DEVELOPMENT OF A SYSTEM-WIDE PREDATOR CONTROL PROGRAM: STEPWISE IMPLEMENTATION OF A PREDATION INDEX, PREDATOR CONTROL FISHERIES, AND EVALUATION PLAN IN THE COLUMBIA RIVER BASIN

Annual Report 1993
VOLUME I - IMPLEMENTATION

Prepared by:

Charles F. Willis

S. P. Cramer and Associates, Inc.

David L. Ward

Oregon Department of Fish and Wildlife

Cooperators:

Oregon Department of Fish and Wildlife
S. P. Cramer and Associates, Inc.
Washington Department of Wildlife
Columbia River Inter-Tribal Fish Commission
University of Washington
National Marine Fisheries Service
Pacific States Marine Fisheries Commission
Oregon State University

Prepared for:

U. S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife Division
PO Box 3621
Portland, Oregon 97208-3621

Project Number: 90-077
Contract Number: DE-BI79-90BP07084

June 1995

CONTENTS

Page

VOLUME II. EVALUATION

VOLUME I. IMPLEMENTATION

Cooperators

Oregon Department of Fish and Wildlife
Columbia River Coordination Section

S.P. Cramer and Associates, Inc.

Washington Department of Wildlife

Pacific States Marine Fisheries Commission

Columbia River Inter-Tribal Fish Commission

University of Washington

National Marine Fisheries Service

EXECUTIVE SUMMARY

by Charles F. Willis

We report our results from the third year of a basinwide program to harvest northern squawfish (*Ptychocheilus oregonensis*) in an effort to reduce mortality due to northern squawfish predation on juvenile salmonids during their emigration from natal streams to the ocean. Earlier work in the Columbia River Basin suggested predation by northern squawfish on juvenile salmonids may account for most of the 10-20% mortality juvenile salmonids experience in each of eight Columbia and Snake River reservoirs. Modeling simulations based on work in the John Day Reservoir from 1982 through 1988 indicated it is not necessary to eradicate northern squawfish to substantially reduce predation-caused mortality of juvenile salmonids. Instead, if northern squawfish were exploited at a rate of 10-20%, reductions in numbers of larger, older fish resulting in restructuring of their population could reduce their predation on juvenile salmonids by 50% or more.

Consequently, we designed and tested a sport-reward angling fishery and a commercial longline fishery in the John Day pool in 1990. We also conducted an angling fishery in areas inaccessible to the public at four dams on the mainstem Columbia River and at Ice Harbor Dam on the Snake River. Based on the success of these limited efforts, we implemented three test fisheries on a multi-pool, or systemwide, scale in 1991 — a tribal longline fishery above Bonneville Dam, a sport-reward fishery, and a dam-angling fishery. Low catch of target fish and high cost of implementation resulted in discontinuation of the tribal longline fishery. However, the sport-reward and dam-angling fisheries were continued in 1992 and 1993. In 1992, we investigated the feasibility of implementing a commercial longline fishery in the Columbia River below Bonneville Dam and found that implementation of this fishery was also infeasible.

Although we were unable to implement an effective longline fishery, it was important to the attainment of program objectives to attempt to substantially increase total annual exploitation. Estimates of combined annual exploitation rates resulting from the sport-reward and dam-angling fisheries remained at the low end of our target range of 10-20%. This suggested the need for additional, effective harvest techniques. During 1991 and 1992, we developed and tested a modified (small-sized) Merwin trap net. We found this floating trap net to be very effective at catching northern squawfish at specific sites. Consequently, in 1993 we examined a systemwide fishery using floating trap nets.

Evaluation of the success of test fisheries in achieving our target goal of a 10-20% annual exploitation rate on northern squawfish, together with information regarding the economic, social, and legal feasibility of sustaining each fishery, is presented in Section II of this report.

The implementation team consisted of the Oregon Department of Fish and Wildlife (ODFW), S.P. Cramer and Associates, Inc. (SPCA), the Washington Department of Wildlife

(WDW), the Columbia River Inter-Tribal Fish Commission (CRITFC), the University of Washington (UW), the National Marine Fisheries Service (NMFS), and the Pacific States Marine Fisheries Commission (PSMFC). ODFW, with assistance from SPCA, was responsible for coordination and administration of the entire program and subcontracted various tasks and activities to WDW, CRITFC, UW, NMFS, and PSMFC based on expertise each brought to the tasks involved in implementing the program. Objectives of each cooperator related to fishery implementation were as follows.

1. ODFW (Report A): Investigate the feasibility of implementing a large-scale, floating trap-net fishery in the Columbia River downstream from McNary Dam.

2. WDW (Report B): Implement a systemwide (Columbia River below Priest Rapids Dam and Snake River below Hells Canyon Dam) sport-reward fishery.

3. PSMFC (Report C): Process and provide accounting for reward payments to participants in the sport-reward fishery.

4. CRITFC (Report D): Implement a systemwide angling fishery at eight mainstem dams on the Snake and Columbia rivers, and investigate juvenile salmonid consumption by channel catfish caught by dam anglers in the lower Snake River.

5. CRITFC (Report E): Investigate the efficacy of removing northern squawfish near hatchery release sites in the Bonneville pool.

6. CRITFC (Report F): Investigate the presence of northern squawfish concentrations in lower reaches of mainstem Snake River and Columbia River tributaries, and collect information regarding the origin and function of documented concentrations.

7. NMFS (Report G): Investigate differences in juvenile salmon survival associated with releases from Bonneville Hatchery at alternative release locations and following removal of northern squawfish by electrofishing.

Background and rationale for the study can be found in Report A of our 1990 annual report (Vigg et al. 1990). Highlights of results of our work in 1993 by report are as follows.

Report A
Implementation of a Floating Trap-Net Fishery for Northern Squawfish in the Columbia River Downstream from McNary Dam

1. An experimental fishery using floating trap nets (modified Merwin traps) in the Columbia River downstream from McNary Dam was implemented to determine its effectiveness in catching large numbers of northern squawfish throughout this area. Special consideration was given to the potential for, and impact on, incidental catches of adult salmonids.

2. Information from a pre-season site survey was used to select fishing locations most likely to be productive areas for capturing northern squawfish with trap nets.

3. We fished 16 trap nets from June 2 through August 4, 1993. A total of 1,392 sets were made with a mean soak time of 2.9 hours. The total catch was 45,803 fishes of which northern squawfish comprised 23% (10,440 fish).

4. Of the total number of northern squawfish caught, 16% (1,688 fish) were within our target range [greater than 11 inches (275 mm) total length]. The mean catch rate of northern squawfish over 11 inches was 0.3 fish per hour. Bycatch of adult salmonids totaled 2 % of the total catch (1,036 fishes).

5. Operational criteria designed to limit incidental take of salmonids restricted dates and times when, and locations where, we could fish. In addition, lack of crew experience with the gear and limited gear effectiveness in areas of high flow velocity below Bonneville Dam contributed to the low harvest rate for northern squawfish.

6. We did not find the floating trap-net fishery to be feasible (in terms of catch versus cost) for implementation on a large scale. However, use of trap nets within the boat restricted zone at The Dalles Dam cul-de-sac each year has been productive in comparison to catches of northern squawfish by dam anglers at that dam. Other selected sites above Bonneville Dam may also produce effective catches of northern squawfish using trap nets on a limited basis and at a reduced cost. We recommend an evaluation of the use of trap nets on a site-specific basis above Bonneville Dam in 1994.

Report B
Evaluation of the Northern Squawfish Sport-Reward Fishery in the Columbia and Snake Rivers

1. Objectives for 1993 were to implement the sport-reward fishery for northern squawfish in the lower Snake and Columbia rivers, to conduct a survey to assess impacts of the fishery on non-target fish species, and to report on the dynamics of the fishery.

2. The northern squawfish sport-reward fishery was conducted from May 3 through September 12, 1993. Twenty registration stations were located throughout the lower Snake and Columbia rivers.

3. A total of 104,616 northern squawfish 11 inches or longer were caught by 15,106 anglers, which represented 43% of the total number of registered anglers (34,879) that participated in the fishery in 1993. Harvest of northern squawfish decreased 44% over that observed in 1992 and 34% over that observed in 1991, with a decrease

in participation of 60 % and 48 % , respectively. The catch per unit effort (CPUE) of 2.99 fish per angler day in 1993 represented an increase of 21% over the catch rate observed in 1992 and 29% over that observed in 1991.

4. Fork lengths of northern squawfish over 250 mm (11 inches total length) averaged 334.7 mm (S.D. 61.6 mm) in 1993, which represented a statistically significant decrease in mean fork lengths between 1992 and 1993. A statistically significant decrease in mean fork lengths was also observed between 1991 and 1992, suggesting a continuing trend in decreased average size of northern squawfish harvested in the sport-reward fishery each year.

5. A total of 2,100 fishes of species other than northern squawfish were returned to registration stations in 1993, representing 2% of the total catch. In order of their frequency of occurrence, peamouth, smallmouth bass, channel catfish, and walleye composed the majority of non-target fishes caught.

7. The portable computerized data collection unit was significantly faster than manual data entry for use in exit interview information and biological data collection, but it was not significantly faster than manual data entry for use in registering participants. Biological data can be collected approximately twice as fast using the computerized data collection system.

8. To obtain additional catch information, we contacted by phone 1,744 (8.8%) out of 19,758 anglers who did not return to exit the sport-reward fishery from stations where they had registered to participate (i.e., non-returning anglers). Sixty-five percent of non-returning anglers reported returning all fish caught to the water unharmed. Ten percent of these anglers reported killing nongame fish and returning fish to the water, and 15% kept fish to eat. Non-returning anglers caught an estimated 2,968 northern squawfish 11 inches or longer in total length. An estimated 19% of these fish were returned to the water unharmed. Only 54% of non-returning anglers failed to exit the fishery through a registration station because they had not caught northern squawfish. Twenty-one percent reported that they did not have enough northern squawfish to make the return to a station worthwhile, and an additional 21% caught only northern squawfish less than 11 inches in total length. Some additional northern squawfish were harvested within the remaining 4% of non-returning anglers contacted who gave their fish away or otherwise disposed of them. A recall bias study (calling returning anglers for whom information was known) indicated that average responses to questions were accurate. Marked differences were observed between estimates of bycatch based on returning angler data alone and estimates based on information obtained via the phone survey. This may be due to a lack of willingness on the part of returning anglers to be detained for questioning following a long fishing day.

9. We recommend that the 1994 sport-reward fishery start in early May and extend through mid-September. Registration stations should be operated with one shift per day extending from 1 p.m. to 9 p.m., seven days per week. Self registration during

periods when stations are closed should continue. Fourteen registration stations should be operated throughout the area in which the fishery was implemented during 1991 through 1993, with the elimination of six stations to accommodate budget reductions and the relocation of one other station to more efficiently accommodate angler use. Use of computerized registration should be discontinued. A streamlined phone survey of non-returning anglers should continue to provide information regarding total catch of target and non-target fishes. An aggressive public relations program should be implemented to increase awareness of, participation in, and efficiency of the sport-reward fishery.

Report C
Northern Squawfish Sport-Reward Payments

1. During 1993, a total of $303,897 was paid to anglers for 101,299 northern squawfish harvested in the sport-reward fishery.

2. Payment activity for the sport-reward fishery was highest during June and July, accounting for about 63% of total dollars paid.

3. The average catch of northern squawfish per voucher ranged from 6.5 fish in May to 9.3 fish in June and July. The mean catch was 8.2 northern squawfish per voucher.

4. Voucher processing proceeded smoothly with checks being cut and mailed to the angler within l-5 days after receipt of the voucher.

5. Vouchers that had missing or incomplete information were returned to anglers for completion causing delay in payment. A total of 646 vouchers were returned. Anglers returned 505 of the vouchers with the information needed for processing.

6. The number of vouchers that were not processed totaled 141 with a combined potential reward of $1,194. There were a variety of reasons for vouchers not being processed. Examples that commonly occurred included failure to complete the required questionnaire and submission of the voucher beyond the deadline for payment.

Report D
Controlled Angling for Northern Squawfish at Selected Dams on the Columbia and Snake Rivers and Diet Analysis of Incidentally Caught Channel Catfish

1. Dam angling at eight dams on the lower Snake and Columbia rivers during 1993 resulted in 16,949 northern squawfish being caught during an l&week season.

2. Total effort and northern squawfish catch decreased 39% and 42 % , respectively, compared to 1992 figures. Overall catch per angler hour was unchanged compared to the 1992 catch rate of 1.7 northern squawfish per hour fished.

3. Effort at Snake River dams decreased 79% since 1991 because of continuing low catch rates (0.5 fish per hour) of northern squawfish. The catch rates of northern squawfish in 1993 at Columbia River dams increased at Bonneville Dam (from 2.7 to 2.9 fish per hour) and John Day Dam (from 1.2 to 2.2 fish per hour) while decreasing at The Dalles Dam (from 3.0 to 1.4 fish per hour) and McNary Dam (from 2.9 to 1.9 fish per hour) compared to 1992 catch rates.

4. Incidental species caught as compared to the total catch decreased slightly from 5.8 % in 1992 to 5.5% in 1993. Contributions to bycatch of bass (*Micropterus* spp.) increased from 1.0% in 1992 to 2.1% in 1993, which partially offset a decrease in the percentage of catfish (*Ictalurus* spp.) caught from 3.7% in 1992 to 2.0% in 1993. Three juvenile and three adult salmonids (*Oncorhynchus* spp.) were caught in 1993, and all except one of the juveniles were released in good condition.

Report E
Removal of Predacious Northern Squawfish Found Near Hatchery Release Sites in Bonneville Pool: An Analysis of Changes in Catch Rates and Diet Associated with the Release of Hatchery-Reared Juvenile Sahnonids

1. Three areas in the Bonneville pool where hatchery-reared juvenile salmonids are released were targeted for investigating distribution and predation activities of northern squawfish. Catch rates of northern squawfish increased significantly after hatchery releases at all three locations.

2. A total of 1,772 northern squawfish were caught from mid-March through mid-May 1993 in 394.4 hours of netting at all locations, yielding a seasonal catch rate of 4.5 fish per hour. Of the total northern squawfish catch, 88.5% were within the target range of 11 inches (275 mm) or larger in total length.

4. Northern squawfish caught after salmonid releases had a significantly higher frequency of occurrence and mean number of juvenile salmonids in their gut compared to fish caught before releases.

5. Consumption indices, used as a relative measure of consumption rates, were also higher at each location after juvenile salmonid releases. Our data suggest that northern squawfish respond numerically and functionally to releases of hatchery-reared juvenile salmonids.

Report F
Investigation of Northern Squawfish Concentrations in Tributaries to the Mainstem Columbia, Snake and Clearwater Rivers

1. Five tributaries along the mainstem Columbia, Snake and Clearwater rivers were examined for northern squawfish concentrations to determine if northern squawfish commonly migrate from mainstem reservoirs into free-flowing tributaries to spawn.

2. A total of 1,686 northern squawfish were captured from May 11 to July 25, 1993, with 1,541 (91%) captured in an upstream migration trap at Threemile Falls Dam on the Umatilla River. None of the fish captured at Threemile Falls Dam bore tags or marks indicating that they originated from mainstem Columbia River areas where northern squawfish were marked and released.

3. The majority (58%) of northern squawfish trapped at Threemile Falls Dam were caught during a one-week period following an increase in the average weekly water temperature from 15° Celsius to 18°C and a decrease in the average weekly flow from 1,705 cubic feet per second (cfs) to 419 cfs. These fish may have originated from the mainstem Columbia River as part of a spawning migration ascending the Umatilla River. Alternatively, they may have (1) been an aggregation of resident fish attempting to reascend the river after having been washed downstream of the dam by high spring flows, (2) aggregated either from the mainstem Columbia or from within the Umatilla River in response to increased prey abundance below Threemile Falls Dam, or (3) aggregated below the dam to escape unsuitable environmental conditions above the dam or in the mainstem Columbia River. Concentrations of northern squawfish are observed at Threemile Falls Dam each year. Future work should attempt to document the origin of these fish.

5. Sampling efforts in the Palouse, Tucannon, and Potlatch rivers, and Lapwai Creek were less successful at locating northern squawfish concentrations. High spring flows may have reduced capture gear efficiency and previously reported concentrations of fish may not have occurred in 1993. Other studies have shown that concentrations of northern squawfish at specific locations are often variable among years. Removal of northern squawfish in prior years may also have reduced the number of fish available for migration into these tributary areas.

Report G
Effectiveness of Predator Removal for Protecting Juvenile Fall Chinook Salmon Released from Bonneville Hatchery

1. Subyearling chinook salmon from Bonneville Hatchery released into the midstream Columbia River prior to electrofishing efforts exhibited significantly higher survival rates than fish released into Tanner Creek at the hatchery. The difference in survival is in part related to predation by northern squawfish on fish released at the hatchery.

2. The predominance of coded-wire tags **(CWTs)** from Tanner-Creek-released juvenile salmon in digestive tracts of northern squawfish indicated that juvenile **salmon** released from the hatchery were more vulnerable to predation by northern squawfish located in the river region near Bonneville Hatchery than juveniles released midstream.

3. The survival difference between midstream Columbia River and Tanner Creek release groups may be affected by the dispersal rate of study fish from the area of release. Faster dispersal may result from higher discharge below Bonneville Dam by affecting hydraulic conditions at the mouth of Tanner Creek. Degree of smoltification may also affect dispersal rate.

4. It was difficult to determine if the high numbers and catch rates of predators at the transects nearest Tanner Creek occurred in response to the hatchery release or to high densities of northern squawfish throughout the study area.

5. It appears that the number and size of northern squawfish in the study area have declined over the study period, perhaps as a result of harvest under the northern squawfish management program, and that this general decline in population abundance contributed to the effectiveness of localized predator removal at Bonneville Hatchery in 1993. Electrofishing to remove northern squawfish from the migration route of juvenile salmon released from Bonneville Hatchery appeared to eliminate the survival difference between **mainstem** Columbia River and Tanner Creek release groups under the conditions that existed in 1993.

REPORT A

Implementation of a Floating Trap-Net Fishery for Northern Squawfish in the Columbia River Downstream from McNary Dam

Prepared by

Christine Mallette

Oregon Department of Fish and Wildlife
Columbia River Coordination Section
17330 S.E. Evelyn Street
Clackamas, Oregon 97015

Thomas K. Iverson, Brian D. Mahoney, and Stephen B. Mathews

University of Washington, School of Fisheries
Maiistop HR-20, Seattle, Washington 98198

1993 Annual Report

CONTENTS

ACKNOWLEDGMENTS

This project was funded by Bonneville Power Administration (BPA) Contract DE-BI79-90BP07084. Franklin R. Young and Kirk T. Beiningen, Oregon Department of Fish and Wildlife (ODFW), administered the contract and critically reviewed the manuscript. Charles F. Willis, S.P. Cramer and Associates, assisted with program coordination.

We thank Gary A. James and Jed W. Volkman, Confederated Tribes of the Umatilla Indian Reservation (CTUIR); Mark A. Fritsch and Henry S. (Hank) Palmer, Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO); Duane Edwards of Fish tec, Environmental Fishery Service; and Manuel Villalobos, Nez Perce Indian Tribe of Idaho (NPT), for their cooperation in project implementation. We extend our thanks to Raymond C. Beamesderfer, ODFW, for supervisory assistance and Sharon L. Conyers, ODFW, for preparation of intergovernmental agreements and personal service contracts.

Thanks to Roy E. Beaty and Blaine L. Parker, Columbia River Inter Tribal Fish Commission (CRITFC); Steven D. King, Suzanne Knapp, and David L. Ward and their staffs, ODFW; Jon Pampush and his staff, Oregon State University; Jim Kuskie and his staff, U.S. Army Corps of Engineers; Thomas P. Poe and his staff, U.S. Fish and Wildlife Service; and Daniel C. Klaybor and his staff, -Washington Department of Wildlife, for their help with project coordination.

Paige M.P. Beamesderfer, ODFW, assisted with compiling and summarizing data for river characteristics and fish abundance. Special thanks to the crews that worked long, odd hours operating trap nets, and collecting and processing the data that is presented in this report. Mike McCloud, CTUIR; Victor Switzler Sr., CTWSRO; Matthew Burrell, Fish tec; Charles Antell, NPT; and Steven J. Banks and Lynn H. Lampkins, ODFW, assisted with coordinating field operations. We thank Preston Bronson, Lewis Case, Brian Conner, and Jim Marsh, CTUIR crew; Christopher Jack III., Allen Jones, Harriman Palmer, Ronald Palmer, and James Teeman, CTWSRO crew; Samuel Antell, Lance Baptiste, Albert Davis, Steve Rueben, and Dina Wilson, NPT crew; Kennex J. Chi, Lisa K. Hjorten, Shirley R. Nelson, Terry R. Thompson, and Erik R. White, ODFW Fishing Crew A; Scott M. Eden, Matt J. DeChambeau, David K. Kieckbusch, Joseph S. Wetton, and William L. Vandervort, ODFW Fishing Crew B; Michael B. Bones, Christopher L. Stephens, and Ty W. Wyatt, ODFW Fishing Crew C; and Travis M. Collier, John A. Fenton, Wesley G. Kelley, and Richard L. Scheele, ODFW moving crew.

Gloria J. Boume and Thomas C. Neill, ODFW, assisted with electronic data entry, verification, and summary. We give special thanks to Thomas A. Rien, ODFW, for assistance with data analysis.

ABSTRACT

Modified Merwin trap nets were tested by an experimental fishery in the Columbia River downstream from McNary Dam to determine their effectiveness in selectively harvesting northern squawfish (*Ptychocheilus oregonensis*) over 11 inches in total length. The fishery was evaluated for its potential to supplement exploitation rates of the sport-reward and dam-angling fisheries to achieve the objectives of the northern squawfish management program. Special consideration was given to the potential for, and impact on, incidental catches of adult salmonids (*Oncorhynchus* spp.) listed as threatened and endangered under the Endangered Species Act (ESA).

Preseason site and data surveys identified suitable fishing locations where physical parameters are favorable to trap-net deployment and northern squawfish habitat was present. A total of 16 floating trap nets were operated from June 2 through August 4, 1993. We made 1,392 sets with a mean soak time of 2.9 hours. The total catch was 45,803 fishes including 10,440 (23 % of the total catch) northern squawfish of which 1,688 (4% of the total catch) were large (greater than 11 inches in total length). Mean catch rate was 0.3 large northern squawfish per hour of soak time. Nearly all incidentally captured fishes were released alive and in good condition. Bycatch of adult salmonids totaled 1,036 fishes (2% of the total catch).

Operational criteria, designed to limit incidental take of salmonids, restricted the fishing time, dates, and locations. In addition, lack of prior operating experience with the gear type and limited gear effectiveness in high velocities found in the free-flowing river below Bonneville Dam contributed to the low harvest rate for northern squawfish. We determined that a large scale floating trap-net fishery outside the boat restricted zones (BRZs) of hydropower projects would not significantly improve the exploitation rate of northern squawfish either above or below Bonneville Dam. However, we recommended that floating trap-net testing be continued on a limited basis at selected sites in the reservoirs above Bonneville Dam where deployment conditions are more favorable to trap-net success. We showed that there is minimal impact, injury, or delay to adult and juvenile salmon from trapnetting, provided that trap nets are maintained faithfully and routinely, and fished when water temperatures are less than 68° Fahrenheit. Consequently, trap nets could be fished in BRZ areas in June and July, with very little effect on salmonids, but with much higher northern squawfish catch rates than we averaged in the present study.

INTRODUCTION

Since 1990, various northern squawfish fisheries have been implemented and evaluated in the Columbia River Basin (Nigro 1990; Willis and Nigro 1991; Willis and Nigro 1992). Angling fisheries (sport-reward fishery and controlled angling at selected hydropower projects) have been implemented annually. In addition, longline gear was tested for applicability to commercial harvest (Mathews et al. 1989; Mathews and Iverson 1990; Vigg et al. 1990; Mallette and Willis 1991; Mathews et al. 1991; Mallette et al. 1992). Longlining resulted in low northern squawfish catch rates, unacceptable high levels of bycatch, and logistical difficulties.

Although absolute catches were highest from implemented angling fisheries, the exploitation rate was still lower than would be likely to significantly reduce northern squawfish predation on salmonids. Consequently, we tested a large-scale floating trap-net fishery to hopefully improve the harvest level above the low end of the 10-20% target exploitation rate. We based our decision to conduct this study on the promising results from limited testing of a modified Merwin trap net by Mathews et al. (1991, 1992a, 1992b) and Lynch (1993). The objectives of the present study were to (1) transfer floating trap-net technology from the University of Washington to ODFW staff and other trap-net operators, (2) refine floating trap-net applications and develop a procedure to acquire quantities of floating trap nets, and (3) stepwise implement a floating trap-net fishery in three reaches of the Columbia and Snake rivers.

METHODS

From December 15, 1992, to February 3, 1993, we conducted a preseason trap-net site survey in the Columbia and Snake rivers (Iverson and Mahoney 1993) to identify the most suitable locations for floating trap-net deployment. Over 200 locations were evaluated for accessibility, trap-net setting qualities, and estimated northern squawfish catch potential. Physical characteristics and northern squawfish habitat requirements were recorded, summarized, and graded for each site.

We compiled available data regarding river contour, substrate, velocity, clarity, and temperature, as well as data regarding northern squawfish abundance and habitat requirements from various regional resource management agencies (data survey). This information was used to confirm and supplement the results of the site survey.

We worked with regional fisheries management agencies to develop an implementation strategy and operational criteria for trap-net deployment in the Columbia and Snake rivers. Uncertainties related to bycatch rates of, and potential impact on, salmonid stocks listed as threatened or endangered under the ESA precluded agreement on criteria for fishery implementation in the Snake River or in boat restricted zones (BRZs) at hydropower projects in the Columbia River. The fishery's objectives were revised to reflect the shift of fishing effort to the remaining midreservoir and free-flowing Columbia River reaches as follows.

We proposed to (1) contract with a single private sector entity to operate a maximum of eight floating trap nets in the free-flowing river reach below Bonneville Dam (Reach I) and (2) contract with four treaty tribes and/or CRITFC to operate a maximum of eight floating trap nets in the river reach from McNary Dam downstream to Bonneville Dam (Reach II). Fishing effort in Reach I was scheduled to start on May 17 and gradually increase over time. Fishing effort in Reach II was scheduled to start June 1. Fishing operations in both reaches were scheduled to cease September 24.

We developed operational criteria for acceptable levels of cumulative salmonid bycatch, handling procedures for incidentally captured adult salmonids, and trap-net relocation. We reviewed spatial and temporal distribution and size of historic and projected 1993 salmonid runs and salmonid bycatch data for previous trap-net studies and provided related recommendations to regional fisheries managers. The subsequently formulated biological opinion and adopted operational criteria for fishery implementation are summarized in Appendix A-l. Additionally, we developed criteria for trap-net relocation based on performance. Adequately deployed trap nets were scheduled to be relocated to a different site if less than 30 northern squawfish were caught per trap-net day.

We modified and refined the design of the floating trap-net unit to improve catch efficiency and mobility. Design modifications were realized through the construction of a prototype trap net and trailer. Deployment of floating trap nets of the modified design proved to decrease the labor intensity of gear assembly and increased trap-net mobility greatly. Specifications for net frames, travel trailers, and nets are summarized in Appendix A-2. ODFW contracted with Fish tec, Environmental Fishery Service, to acquire quantities of trap-net units prior to fishery implementation. We prepared for limited deployment of alternative, sunken Pennsylvania (Lake Erie) style trap nets if sufficient quantities of floating trap nets were unavailable at the start of the fishery.

We conducted trap-net seminars and workshops for participating fishing crews prior to the start of the fishing season.

Solicited contracts for inseason trap-net operations were modified significantly to accommodate the limiting time schedule. For Reach I, fishing and moving crews were staffed with ODFW employees. In terms of trap-net operations, private sector involvement was limited to supervisory functions related to trap-net relocation and maintenance. Only three contracts were completed for operations of two trap nets each in Reach II. Tribal contractors encountered staff shortages and equipment downtime to varying degrees. One tribal crew experienced significant effort loss due to a malfunctioning vessel that could not be replaced inseason. A proportion of the effort loss was compensated by the formation of a third ODFW fishing crew that operated trap nets in Bonneville Reservoir. However, the overall effort loss in Reach II was significant. The discrepancy of trap-net effort among river reaches above and below Bonneville Dam was addressed inseason by transferring one fishing crew and five floating trap nets from Reach I to Reach II during the last week of July. All trap-net activities ceased immediately following gear translocation based on fishery non-compliance with prescribed operational criteria (excessive water surface temperature).

The study area in the lower Columbia River was divided into six transections as follows:

Area	From	Upstream To
1	West End Puget Island (RM[1] 38)	Bachelor Point (RM 92)
2	Bachelor Point (RM 92)	Bonneville Dam (RM 145)
3	Bonneville Dam (RM 145)	The Dalles Dam (RM 191)
4	The Dalles Dam (RM 191)	John Day Dam (RM 217)
5	John Day Dam (RM 217)	Six Mile Canyon (RM 260)
6	Six Mile Canyon (RM 260)	McNary Dam (RM 293)

[1] Standard river mile.

The fishery was implemented seven days per week from June 1 through August 4. On this, date water surface temperatures exceeded 68° F (see Operational Criteria, Appendix A-l). Three ODFW and three tribal fishing crews (each staffed with two shifts and three or more persons per shift) fished a total of 16 trap nets. One trap-net relocation and maintenance (moving) crew (staffed with two shifts and three persons per shift) assisted with trap-net operations in Areas 1 and 2.

Fishing crews recorded data regarding location (river mile and site description), soak time (the cumulative amount of time that the net was open), water depth, temperature, and clarity, distance from the net entrance to shoreline, and catch (species, life stage, condition, and disposition) for each set (Appendix A-3, Appendix Figures A-3.1 and A-3.2). Fishing crews collected subsample fork length data on the northern squawfish catch. Non-target fish including northern squawfish of less than 11 inches in total length were quickly released. We clipped the caudal fins of all harvested northern squawfish, transported them to local field stations, and stored them in freezers until collection by Oregon State University personnel.

The moving crew recorded trap-net relocations on a form (Appendix A-3, Appendix Figure A-3.3). In addition, most crews used cellular phones to frequently update catch information and net location status.

Data forms were transmitted daily from various field offices to the main project office in Clackamas for electronic data entry, verification, and summary. Weekly preliminary catch summaries (Weekly Field Activity Reports) were generated on Mondays for the previous week. Weeks are defined as starting on Mondays (except Week 1, which started on Tuesday, June 1) and ending on Sundays (except Week 10, which ended on Wednesday, August 4).

To ensure compliance with operational criteria, we monitored current salmonid run size data as they were made available.

RESULTS

Effort

Sixteen floating trap-net units were used by six fishing crews (CTUIR, CTWSRO, NPT, ODFW-A, ODFW-B, and ODFW-C) from June 1 through August 4. Numbers of nets used per fishing crew varied from 0 to 5 depending on logistical constraints, availability, and distance between trap-net locations that were fished simultaneously. Table A-l shows maximum numbers of trap nets deployed by crew and area. All but CTWSRO and NPT crews fished in one area only.

Fishing crews made a total number of 1,392 sets. Appendix A-4, Appendix Table A-4.1 demonstrates numbers of sets by area and week. Values for Area 1 and Week 1 include effort of two sets made on June 2 where sunken Pennsylvania trap nets were used in lieu of sufficient numbers of available floating trap nets. Also included are three floating trap-net sets that were accidently made just above the BRZ area of the McNary Dam forebay (Area 7).

The number of sets per week increased steadily over time from 91 (Week 2) to 258 (Week 9). Effort was focused on the lower sampling areas with the majority of sets (853, or 61%) made in Areas 1 and 2. The cumulative number of lower sampling area sets increases to 1,073 or 77%, if Area 3 is included. Appendix A-4, Appendix Table A-4.2 shows numbers of sets made by crew, area, and week. Fishing crews averaged 31.5 sets per week, (excluding Weeks 1 and 10) and ranged from 11 (CTWSRO crew) to 53.8 (ODFW-B crew) sets per week.

Table A- 1. Maximum number of floating trap nets deployed by crew and area.

Area	No. of trap nets	Fishing crew	Dates From	Dates To
1	4	ODFW-A	Jun. 02	Jul. 28
2	3	ODFW-B	Jun. 01	Aug. 04
3	2[1]	CTWSRO[2]	Jun. 12	Aug. 04
	3	ODFW-C	Jul. 07	Aug. 04
4	2[1]	CTWSRO	Jun. 03	Jun. 05
	2[3]	NPT		
5	2[3]	NPT		
6	2[3]	NPT		
	2	CTUIR	Jun. 29	Aug. 04

[1] Identical trap nets.
[2] Trap nets were fished by CIWSRO crew through July 04 and permanently transferred to the ODFW-C crew on July 26.
[3] Identical trap nets.

Total soak time was 4,051 hours with a mean soak time of 2.91 hours per set (Appendix A-4, Appendix Table A-4.1). For each area, mean soak time per set ranged from 2.57 (STD = 1.99) in Area 2 to 3.44 (STD = 2.6 1) in Area 4. Figure A-l illustrates increasing cumulative soaking hours over time from 197 (Week 2) to 793 (Week 9) hours as was expected with increasing effort (numbers of sets).

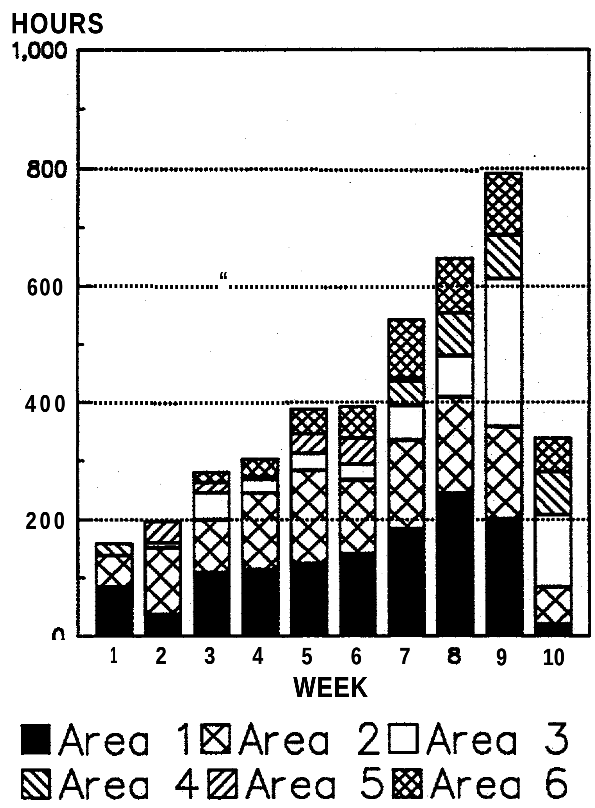


Figure A-l. Effort in Hours by Week and Area

Appendix A-4, Appendix Table A-4.2 shows cumulative soak times by crew, area, and week. Crews averaged 89.76 hours per week (excluding Weeks 1 and 10) with a range from 26.91 (CTWSRO crew) to 144.24 (ODFW-A crew). Appendix A-5, Appendix Figure A-5.1 lists cumulative soak time by area and fishing crew. The CTWSRO crew expended the least amount of effort (3% of the total soak time). Effort expended by CTUIR, NPT, and ODFW-C crews was comparable (11%, 11% , and 13 % , respectively) and ODFW crews B and A expended the most effort (30% and 31% , respectively).

The ODFW-A crew made fewer sets (27% -of 1,392) with a higher mean soak time (114% of 2.91) per set. The ODFW-B crew made more sets (34% of 1,392) with a lower mean soak time (88% of 2.91) per set (Appendix A-4, Table A-4.1). Resulting net differences in numbers of sets made and mean soak times per set for ODFW-A and ODFW-B crews are 25 % and 29%, respectively.

Catch

A total of 45,803 fishes were caught. Appendix A-4, Appendix Table A-4.3 lists total catch by family and species. Cyprinids (minnows) comprised 74.6% of the total catch, salmonids 5.5%, and centrarchids (sunfishes) 5.3%.

Northern Squawfish Catch

Northern squawfish comprised 22.8% (10,440 fish) of the total catch. Most of the northern squawfish caught (8,752 fish, or 83.8% of the northern squawfish catch) were fish smaller than 11 inches in total length. Figure A-2 illustrates northern squawfish catch by area and size class.

Figure A-3 shows northern squawfish catch by week. Catch increased steadily over time for both size classes and averaged 196 large and 987 small fish per week (excluding Weeks 1 and 10).

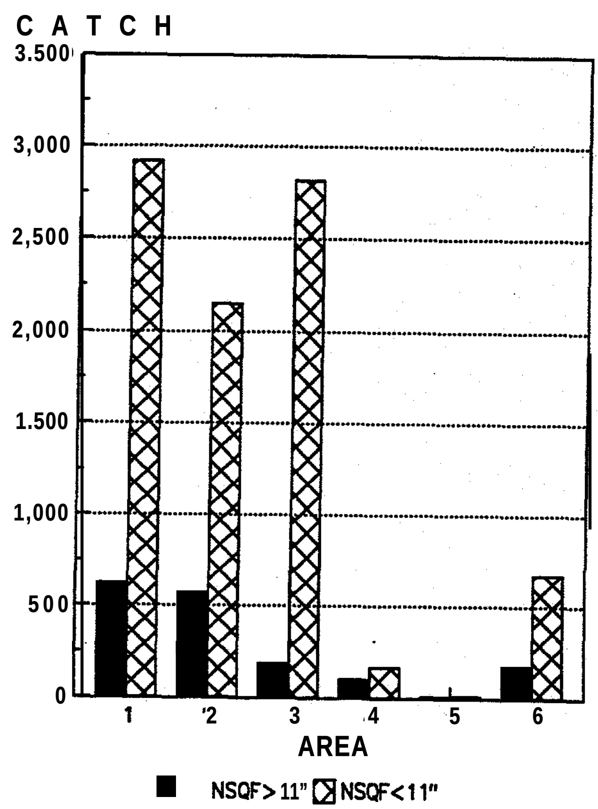


Figure A-2. Northern squawfish catch by area and size class.

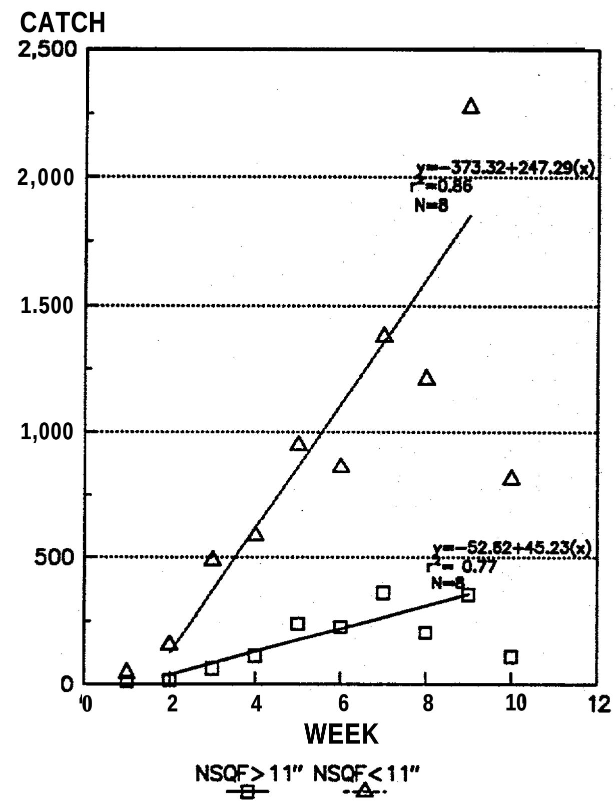


Figure A-3. Northern squawfish catch by week and size class.

Catch per unit of effort (CPUE) increased over time for northern squawfish of both size classes (Figure A-4). Appendix A-5, Appendix Figure A-5.2 shows CPUE by area. CPUE for large northern squawfish averaged at 0.3 fish per hour (or 0.9 fish per set) with lowest catch rates occurring in Area 5 and highest in Area 1. Area 3 yielded highest overall northern squawfish CPUE (4.68 fish per hour), approximately twice as high as Areas 1 or 2. Appendix A-5, Appendix Figure A-5.3 shows CPUE by fishing crew. Again, CPUE for overall northern squawfish catch is high for fishing crew ODFW-C, which operated strictly in Area 3. The CTUIR crew achieved highest catch rates (0.38 fish per hour) for large northern squawfish, approximately four times as high as the average.

Fork lengths were taken randomly from 1,105 fish, 10.6% of the catch. Mean fork length for all northern squawfish sampled was 244 mm (SDE = 83.26). Mean fork length for large northern squawfish (492 fish) was 318 mm (SDE = 63.32) ranging from 295 mm in Area 3 (N=16) and Area 6 (N=28) to 358 mm in Area 5 (N= 11). Mean fork length for small northern squawfish (613 fish) was 185 mm (SDE = 36.72). Appendix A-5, Appendix Figure A-5.4 illustrates related fork length frequency. Most frequent (80%) were fish measuring from 130 mm to 310 mm in fork length.

Salmonid Bycatch

Salmonid bycatch comprised 5.5 % (2,5 16 fishes) of the total catch and was classified by species and life stage (Figure A-5). Life stage was not recorded for one salmonid caught in Area 5 during Week 3. Adult and jack salmonid bycatch comprised 41.2% (1,036 fishes) of the overall salmonid bycatch. From the returning adult salmonids (including jacks) that were identified by species, 63% (653 fish) were steelhead (*Oncorhynchus mykiss*) and 30.8% (319 fish) were sockeye salmon (*Oncorhynchus nerka*). The majority of juvenile salmonids (94.7%, or 1,400 fishes) were not identified by species.

Figure A-6 shows salmonid bycatch by area and life stage. Most salmonids (79.2% of 2,515 fishes) as well as the majority of the adults (80.6% of 1,036 fishes) were captured in Areas 1 and 2.

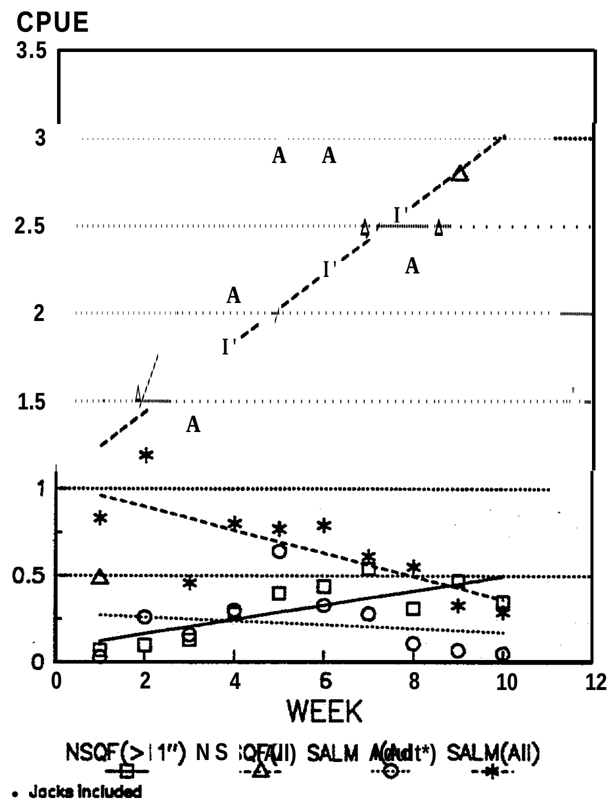


Figure A-4. Catch per unit of effort (CPUE) for northern squawfish and salmonids by week.

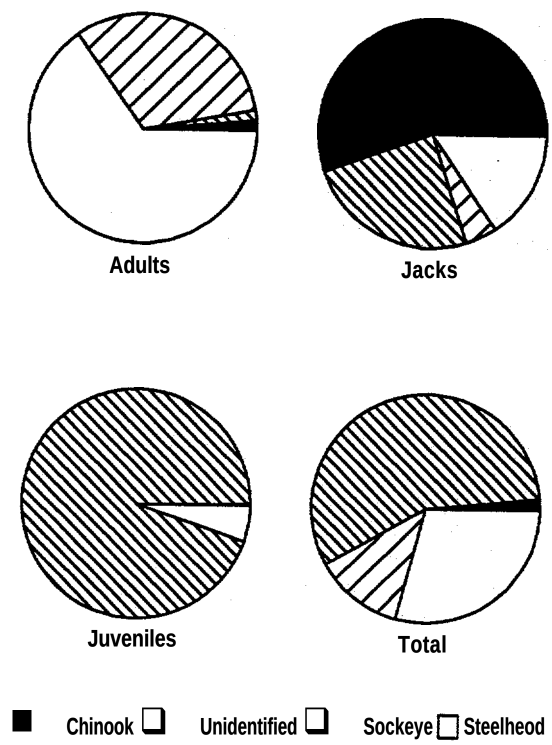


Figure A-5. Salmonid bycatch by species and life stage.

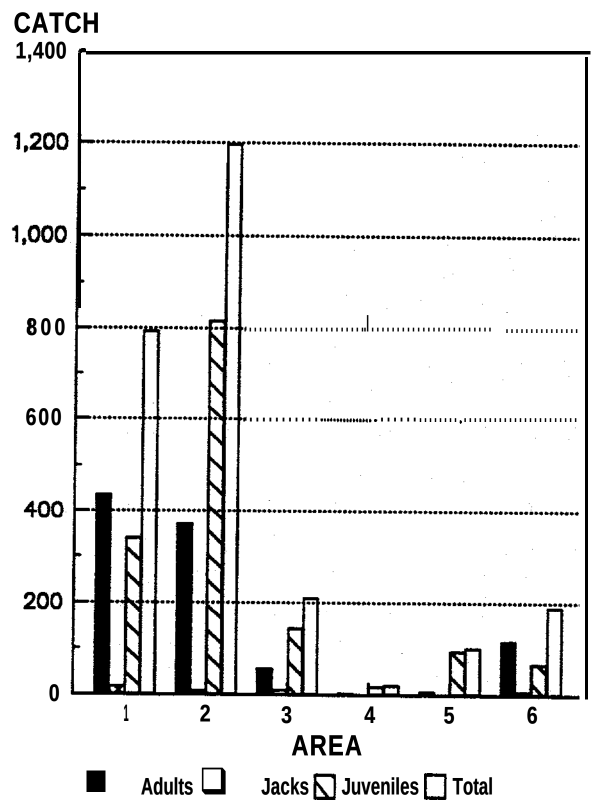


Figure A-6. **Salmonid bycatch** by area and life stage.

Bycatch per unit of effort (CPUE) decreased over time (Figure A-4). Appendix A-5, Appendix Figure A-5.2 shows CPUE by area. CPUE for adult salmonids (including jacks) averaged at 0.15 fishes per hour (or 0.5 fishes per set) with lowest catch rates occurring in Area 4 and highest in Area 1. Area 2 yielded highest overall salmonid bycatch CPUE of 0.98 fishes per hour, followed by Area 5 (0.72 fishes per hour). Appendix A-5, Appendix Figure A-5.3 shows CPUE by fishing crew. Again, CPUE for overall salmonid bycatch is high for fishing crew ODFW-B, which operated strictly in Area 2. CTUIR and ODFW-A fishing crews accounted for the highest bycatch rates (0.37 fishes per hour) for adults and jacks, approximately twice the average.

Appendix A-5, Appendix Figures A-5.5 and A-5.6 illustrate release conditions for adult (including jacks) and juvenile salmonids by species. Most fish (93.6%, or 2,354 fishes) were released in good condition and only 0.5% (12 juveniles) were not expected to survive or were dead. Measurable gear and handling impact on incidentally captured salmonids was negligible.

DISCUSSION AND CONCLUSIONS

Success in trapnetting northern squawfish, particularly large (> 11 inches in total length) individuals, was less during this study than anticipated from previous results using Merwin trap nets on the Columbia River and elsewhere. In the past, floating trap nets have worked well, particularly when fished on known or probable concentrations of adult northern squawfish during the spawning season (June and July), -when their upstream migrating proclivities make them susceptible to such gear. The reasons for the relative lack of success during 1993 are complex and not solely a reflection of the technical inadequacies of this gear. However, the 1993 project did serve to emphasize not only the specific circumstances under which floating trap nets may not be very successful, but also the physical limitations and handling problems associated with such gear.

The circumstances contributing to the relatively low overall catch rates can be categorized as (1) administrative or logistical, and (2) technical.

The major administrative and logistical problems encountered during the current project were as follows:

1. Delay in starting date.

2. Compacting of time for gear construction and acquisition.

3. Insufficient site-specific background.

4. Vessel breakdowns.

5. ESA constraints on times and locations of operation.

6. Insufficient communication among the various participants (ODFW, Tribes, UW, Fish tec).

The major technical difficulties included:

1. Inadequate design for use in swift currents.

2. Relative immobility of gear.

3. Need for constant maintenance.

4. Requirement of active migration of fish to be effective.

Discussion follows on each of these points.

Delays in completing contract negotiations resulted in a delayed starting date for the fishery. Concerns had to be resolved regarding (1) the scope of the fishery, (2) the potential for impact on adult salmonids in terms of delayed migration and stress, (3) the spatial distribution of fishing activities conducted by ODFW versus tribal employees, (4) the extent of private sector involvement, and (5) implementation cost. Thus, even though field work was scheduled to start in early June, in fact it was several weeks into the season before a full-scale evaluation effort was launched. In past years, June has been one of the best months for trapnetting large northern squawfish, probably because it is the major month of migratory activity associated with spawning.

The delays in start-up caused reduction in time periods allocated for contracting, manufacture, and delivery of gear. In turn, this caused fewer and less cost-effective choices and a lack of opportunities to allow for preseason adjustments.

The site survey was conducted in early winter under very cold, icy, and windy weather conditions. Subsequently, most of the described site-specific conditions were not representative for the actual fishing season. Most of the information collected and evaluated in the data survey was not specific to sites for trap nets, but rather specific to a broader area. Therefore, the contributions of these surveys to the development of criteria for trap-net site selection were limited. Ideally, the site survey would have been done during months of anticipated operation.

Most of the people hired to operate the trap nets had no prior experience with such gear or similar gear. Some had minimal or no small-boat handling or maintenance experience. Short workshops prior to operation were helpful, but experience is the only really effective way to learn the use of this gear, and it may take a full season to develop an optimally trained crew. Inseason technical support and cooperation reached satisfactory levels, resulting in harvest technology being eventually transferred successfully from UW to

ODFW and tribal staffs. However, by the time most project employees were well trained, optimal times for trapnetting northern squawfish had passed.

Minor vessel breakdowns were encountered, and in one instance a major loss in test effort occurred because of a malfunctioning vessel that could not be repaired or replaced in a timely manner. Such breakdowns in vessels are not a direct reflection on efficiency of the trap-net gear, itself. However, vessels are an integral part of a mobile trap-net operation; trap nets should be readily movable from unproductive sites to potentially better ones. Without smooth-running, efficient work boats, such mobility is lost. Any marine operation relying on vessels can expect a certain level of mechanical problems. The best way to minimize such difficulties is with the acquisition of adequate vessels and with crews experienced in vessel maintenance and repair.

Perhaps the greatest single factor in the relatively low northern squawfish catch rates in 1993 was the ESA constraint on fishing the BRZ areas below the dams. Most previous research on both trapnetting and the distribution and behavior of northern squawfish has shown that northern squawfish concentrations are far higher in BRZ areas than elsewhere, particularly in the summer. Such concentrations are due to two factors. First, northern squawfish innately tend to move upstream to spawn. Since they now encounter dams and probably have limited (although some) proclivity to ascend ladders, their numbers tend to build up immediately below dams during the spawning season. Second, as is only too well known, northern squawfish actively seek salmonids in their diets; consequently, outmigrating smolts weakened in the spillway or turbine in their exodus past the dams create feeding concentrations below the dams. Therefore, trap-net sites within the eliminated BRZ areas, including those in the Snake River reaches, could have greatly contributed to the harvest rate of large northern squawfish (Mathews et al. 1991, 1992a, and 1992b; Iverson and Mahoney 1993).

An unfortunate by-product of the project's late start was a lack of understanding of roles and responsibilities among participants. This created some significant gaps in making decisions about such items as where to place trap nets and when to move them from unproductive sites to alternative sites. It is common sense strategy when testing new fishing gear or exploring new grounds to be as mobile and flexible as possible. In retrospect, we did not achieve an optimal level of flexibility. Ideally, we should have fished more sites with less time on average per site. Improved and refined strategies are needed to coordinate prescribed trap-net relocations more effectively.

The present floating trap net is not adaptable to the high water velocities and tidal influences found in the free-flowing reaches below Bonneville Dam. Even moderate currents pushed the trap-net lead and heart out of shape, and currents created anchoring and debris problems. These problems were anticipated, and prior to this project, funding for developing and testing alternative trap nets specifically designed for swifter currents had been requested. However, since such funding requests were not met, we were left with the less than satisfactory alternative of testing the present trap-net design below Bonneville Dam to see if or how it might be successfully deployed in current. Gear effectiveness under these conditions could be improved by further design modifications and alternative deployment schedules.

The present design, even though it is more mobile than Merwin trap nets, is still a relatively cumbersome, unfamiliar piece of gear, compared with gill nets, longlines, or seines. It takes several people, an efficient work skiff, a launching ramp, and two or three hours to set or pull a net. When crews get short-handed or overworked, a natural outcome is that trap nets may not be moved often enough in response to the ever-changing distribution and behavior of the fish. Furthermore, the gear requires regular and dependable maintenance. Web and lead should often be cleaned of algae, particularly as temperatures increase.

Finally, this is a passive gear (i.e., catch rates are directly dependent upon fish movements). The best time to use such gear is during June and early July when spawning northern squawfish have a natural tendency to move upstream. The peak of such activity may have been passed by the time the crews gained sufficient experience.

Effort levels were adequate in Areas 1 and 2 (downstream from Bonneville Dam), but only moderate to low in Areas 3 through 6. Catch composition resembled results of earlier mobile Merwin trap-net studies (Mathews et al. 1992a) with respect to northern squawfish catch and combined bycatch of other cyprinids and centrarchids. The ratio of large to small northern squawfish decreased substantially compared to 1992 data, possibly as a result of sampling site characteristics (moderate to poor habitat for piscivorous northern squawfish). Contrary to this year's implementation, fishing locations in 1992 included BRZ areas at hydropower projects where 49.4% of the effort and 74.6% of the northern squawfish catch occurred. Salmonid bycatch was lower than 1992 results as was expected as a probable cumulative effect of the elimination of sampling sites within BRZ areas and generally smaller salmonid run sizes.

The floating trap nets as deployed in this study had a relatively high cost per fish, Thus, this method is impractical to pursue on a large scale throughout the reservoirs or below Bonneville Dam, particularly given the level of constraints imposed to achieve standards set for incidental salmonid catches. However, we showed in this study (as has been previously demonstrated) that handling stress and delays on adult and juvenile salmon from trap nets is minimal, either absolutely or relative to other standard fishing or sampling methods such as gillnetting, electrofishing, or seining. Therefore, considering the high trapnetting success rate in BRZ areas of previous studies, we recommend that limited further test efforts with trap nets should continue, especially above Bonneville Dam. And specifically, state and federal agencies and tribes should continue to review the concept of BRZ-specific deployment of trap nets in June and July.

REFERENCES

Iverson, T.K., and B.D. Mahoney. 1993. Columbia and Snake River mobile trap site survey. University of Washington, School of Fisheries, Seattle.

Lynch, J.M. 1993. Evaluation of the merwin trap as a means of northern squawfish (Ptychocheilus oregonensis) control in the Columbia River. Master thesis. University of Washington, School of Fisheries, Seattle.

Mallette, C., and C.F. Willis. 1991. Implementation of a tribal longline fishery for northern squawfish in Bonneville, The Dalles and John Day Reservoirs. Pages 9-39 in C.F. Willis and A.A. Nigro, editors. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries and evaluation plan in the Columbia River basin. 1991 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

Mallette, C., S.J. Banks, T.C. Neill, and P.M. Pierce. 1992. Feasibility investigation of a commercial longline fishery for northern squawfish in the Columbia River below Bonneville Dam. Pages 9-54 in C.F. Willis and A.A. Nigro, editors. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries and evaluation plan in the Columbia River basin. 1992 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

Mathews, S.B., T.K. Iverson, and R.W. Tyler. 1989. Evaluation of harvesting technology for potential northern squawfish commercial fisheries in Columbia River reservoirs.Pages 278-354 in A.A. Nigro, editor. Developing a predation index and evaluating ways to reduce salmonid losses to predation in the Columbia River basin. 1989 Annual report. Contract DE-AI79-88BP92122, Bonneville Power Administration, Portland, Oregon.

Mathews, S.B., and T.K. Iverson. 1990. Evaluation of harvest technology for potential squawfish commercial fisheries in Columbia River reservoirs. Pages 261-326 in A.A. Nigro, editor. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries and evaluation plan in the Columbia River basin. 1990 Annual report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

Mathews, S.B., T.K. Iverson, J.M. Lynch, B.D. Mahoney, and R. W. Tyler. 1991. Evaluation of harvest technology for squawfish in Columbia River reservoirs. Pages 209-229 in C.F. Willis and A.A. Nigro, editors. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries and evaluation plan in the Columbia River basin. 1991 Annual report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

-Mathews, S.B., T.K. Iverson, J.M. Lynch, and B.D. Mahoney. 1992a. Evaluation of harvest technology for squawfish control in Columbia River reservoirs. Pages 183-294 in C.F. Willis and A.A. Nigro, editors. Development of a systemwide predator control program: Stepwise implementation of a predation index, predator control fisheries and evaluation plan in the Columbia River basin. 1992 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

1992b. Northern squawfish harvest technology: implementation feasibility in -Columbia River. Special issue paper. University of Washington, School of Fisheries, Seattle.

Nigro, A.A., editor. 1990. Development of a system-wide predator control program: stepwise implementation of a predation index predator control fisheries and evaluation plan in the Columbia River basin. Annual report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

Vigg, S., C.C. Burley, D.L. Ward, C. Mallette, S. Smith, and M. Zimmerman. 1990. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. Report A *in* A.A. Nigro, editor. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River basin. Oregon Department of Fish and Wildlife, Contract DE-BI79-90BP07084. Annual Report to Bonneville Power Administration, Portland, Oregon.

Willis, C.F., and A.A. Nigro, editors. 199 1. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries and evaluation plan in the Columbia River basin. Annual report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

Willis, C.F., and A.A. Nigro, editors. 1992. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries and evaluation plan in the Columbia River basin. Annual report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

APPENDIX A-1

Operational Criteria

Operational Criteria Applicable to the Floating Trap-net Fishery for Northern Squawfish in the Columbia and Snake Rivers.

<u>In:</u> Biological opinion under Section 7 of the Endangered Species Act (ESA) on operation of the Federal Columbia River Power System (FCRPS) through January 31, 1994. 1993. National Marine Fisheries Service (NMFS). Washington D.C.

(1) Bonneville Power Administration (BPA) shall not operate Merwin trap nets or conduct any type of trapnetting in the Snake River in 1993.

(2) BPA shall not operate trap nets in the Columbia River when water temperatures exceed 68° Fahrenheit.

(3) BPA shall not hold adult or juvenile salmonids longer than 3 hours during the period of May 31 through September 30.

(4) BPA shall not operate trap nets within 500 feet of any fishway entrance.

(5) Between May 31 and September 30, if water temperatures are below 68" Fahrenheit, only nighttime fishing (from one hour after sunset until one hour before sunrise) will be conducted. However, if ***Oncorhynchus nerka*** are present at Bonneville Dam prior to May 31, then only nighttime fishing will be allowed, beginning on the date of first detection.

(6) BPA shall not conduct Merwin trapnetting in dam boat restricted zones (BRZ's) from May 31 through September 30.

(7) If, during three-hour periods (between May 31 and September 30), any one of the following criteria occurs, trap-net operation at the affected site will cease.

    (a) Salmonid to northern squawfish ration exceeds 1: 1.

    (b) Salmonid catch rates exceed 20 per three hours of trap-net effort.

    (c) Density criteria for fish held in the trap net exceed 2.0 pounds per cubic foot of water with a water temperature of 50° F when adult salmonids are present. For each degree of water temperature below or above 50° F, the poundage can be increased or decreased 5%, respectively (Senn et al. 1984).

(8) Outside of the May 31 through September 30 period, four-hour maximum holding times will be followed except:

(a) If any of the above criteria are met (7.a-b), maximum holding-time will not exceed three hours; or

(b) If any of the above criteria (7.a-b) are met during a three-hour period, fishing at the affected site will cease.

(9) BPA shall cease all trapnetting operations if cumulative incidental catch of salmonids exceeds cumulative catch criteria developed by the Oregon Department of Fish and Wildlife (February 10, 1993, memorandum from R. Boyce, ODFW, to Fish Passage Advisory Committee).

(10) The criteria for resuming trapnetting at a given site following cessation (according to Section X.B.7.a.7) will be based on re-initiation of consultation with NMFS.

(11) The criteria for resuming trapnetting following a period of cessation (according to Section X.B.7.a.9) will be based on salmonid ladder counts and smolt collection data. Fishing will only resume when NMFS determines that such data indicate that salmonid abundance has dropped below the threshold levels that triggered cessation of trapnetting.

(12) Adult salmonids and other incidental species, when possible, will be released over the cork line or through a net opening designed for release. However, if the operator judges dipnetting to be less harmful, soft-meshed shallow dip nets will be used. Since fishing will not occur at temperatures above 68 Degrees Fahrenheit, and holding times will be short, it is reasonable that in the absence of a better method, occasional dipnetting should be allowed to minimize release stress.

(13) BPA shall conduct additional investigation of alternative release methods for incidentally caught adult salmonids.

APPENDIX A-2

Gear Specifications

Floating Trap-Net Frame

The frame consists of five basic sections. The two pontoons are identical, making them interchangeable. Each pontoon is approximately 24 feet long, 24 inches wide, and 20 inches tall. The pontoons are constructed from .125-inch 5052 alloy aluminum, break-formed to eliminate as many welded seams as possible. Each pontoon has a watertight subdeck that is also made of individual watertight compartments, each having an inspection-access plate. Tie-down loops are provided on each side of the pontoons for attaching the trap net and bumper floats. Each pontoon has eight lo-inch welded aluminumcleats placed as per prints. Reinforced towing eyes are welded on both ends of each pontoon. The pontoons are equipped with two single speed sailboat winches placed on reinforced pads on each end of the pontoons. Sockets for removable handrails are placed on the outboard side of each pontoon. Eight removable deck boards, constructed of .75-inch marine grade plyboard, allow access to the storage area above the watertight deck. These deck boards form the walking deck of the pontoons. The watertight deck and the walking deck are painted with non-skid paint.

Three cross-deck walkways connect the two pontoons. Each walkway is 14 feet long and identical, making them interchangeable. The walkways are also break-formed from .125-inch 5052 aluminum. The walkways are attached to the pontoons with quick-connect pins made from one-inch stainless steel shafting. The walking surfaces are painted with the same non-skid material as the pontoons.

Floating Trap-Net Trailer

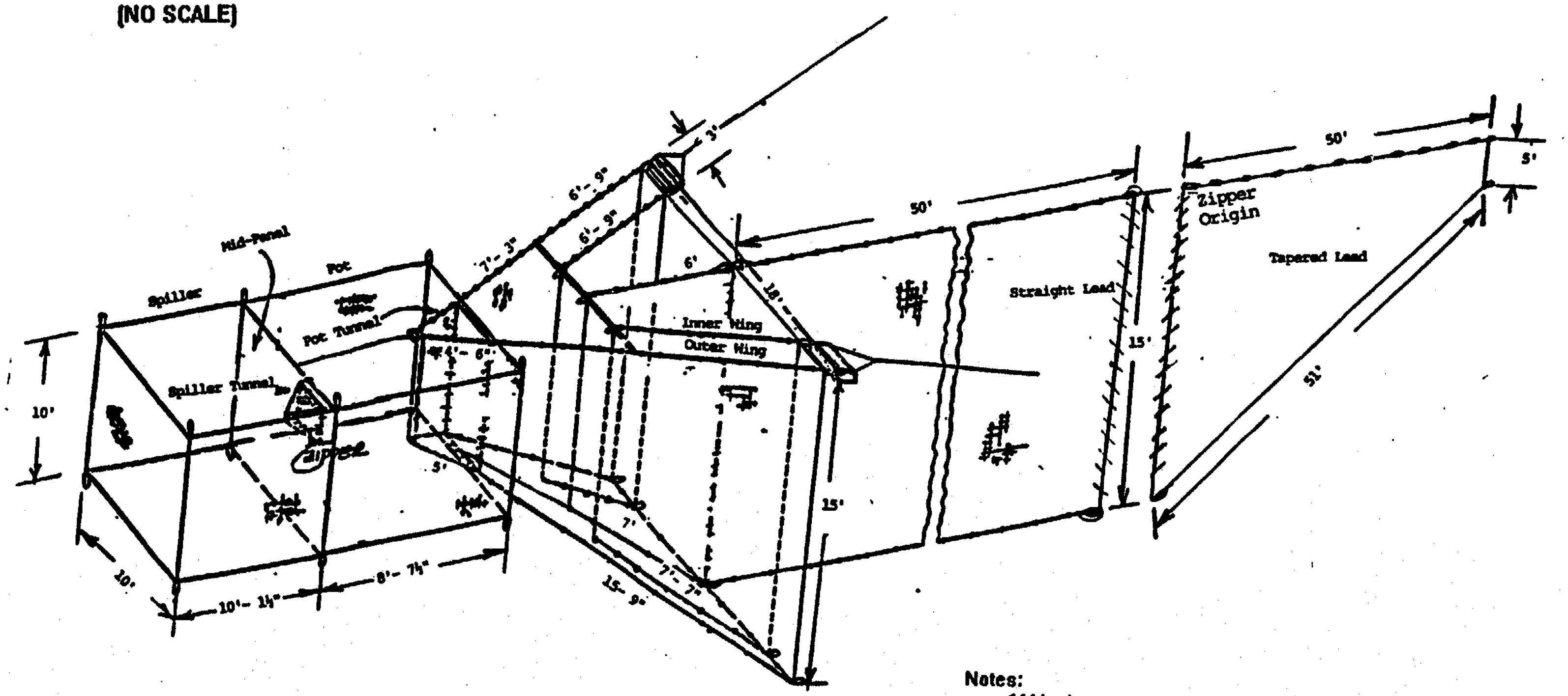
The trap-net trailer is designed to carry two complete floating trap-net frames, two trap nets, and the necessary ancillary gear such as anchors, lines, etc. Design is such that a crew of three persons can load the frames and gear. The trailer is approximately 26 feet long and 7 feet wide. Construction is of 2x2-inch and 2x4-inch tandem axle design, with “walking axle” configuration. The coupler is fitted near the front of the trailer. Tail lights, break lights, and turn indicator are provided and wired to an industry standard seven-prong coupler. Two amber and one red reflector are placed on each side. A license plate bracket is placed at the rear of the trailer. The center of the trailer is a net and gear storage galley. The side boards and deck of the galley are one-inch plyboard. A removable plyboard tailgate is at the rear of the net galley. Tie-down rings are welded to the trailer as per prints. Areas where the pontoons bear on the trailer frame is to be completely sandblasted prior to painting. Finish is to consist of a two-part epoxy primer and gloss top coat.

Appendix Figure A-2.1. Floating trap net.

University of Washington Mobile Squawfish Trap

15' Net Layout

(NO SCALE)



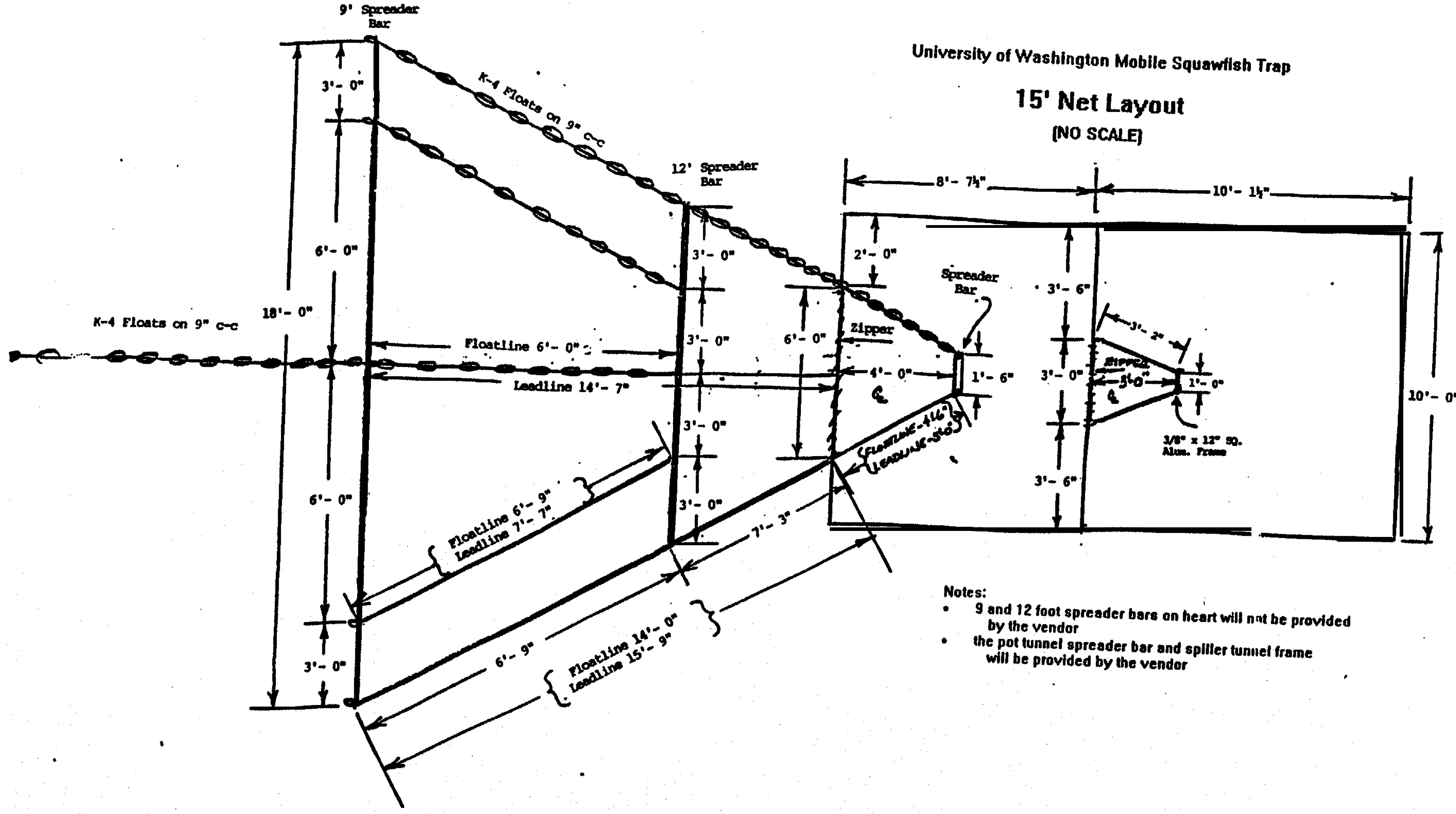
Notes:

- 1¾ inch stretch mesh, #252 knotless nylon netting
- 3/8 inch braided polypropylene framing lines and corklines
- 4 pound per fathom leadlines (Sampson Flexcore or equivalent)
- 2 pound per fathom leadlines in spiller tunnel only
- Y.K.K. #10 separating zippers
- Spongex K-4 expanded PVC floats or equivalent
- green water-base latex netcoat (Flexdip Netcoat or equivalent)
- see attached verbal description for further instructions

University of Washington Mobile Squawfish Trap

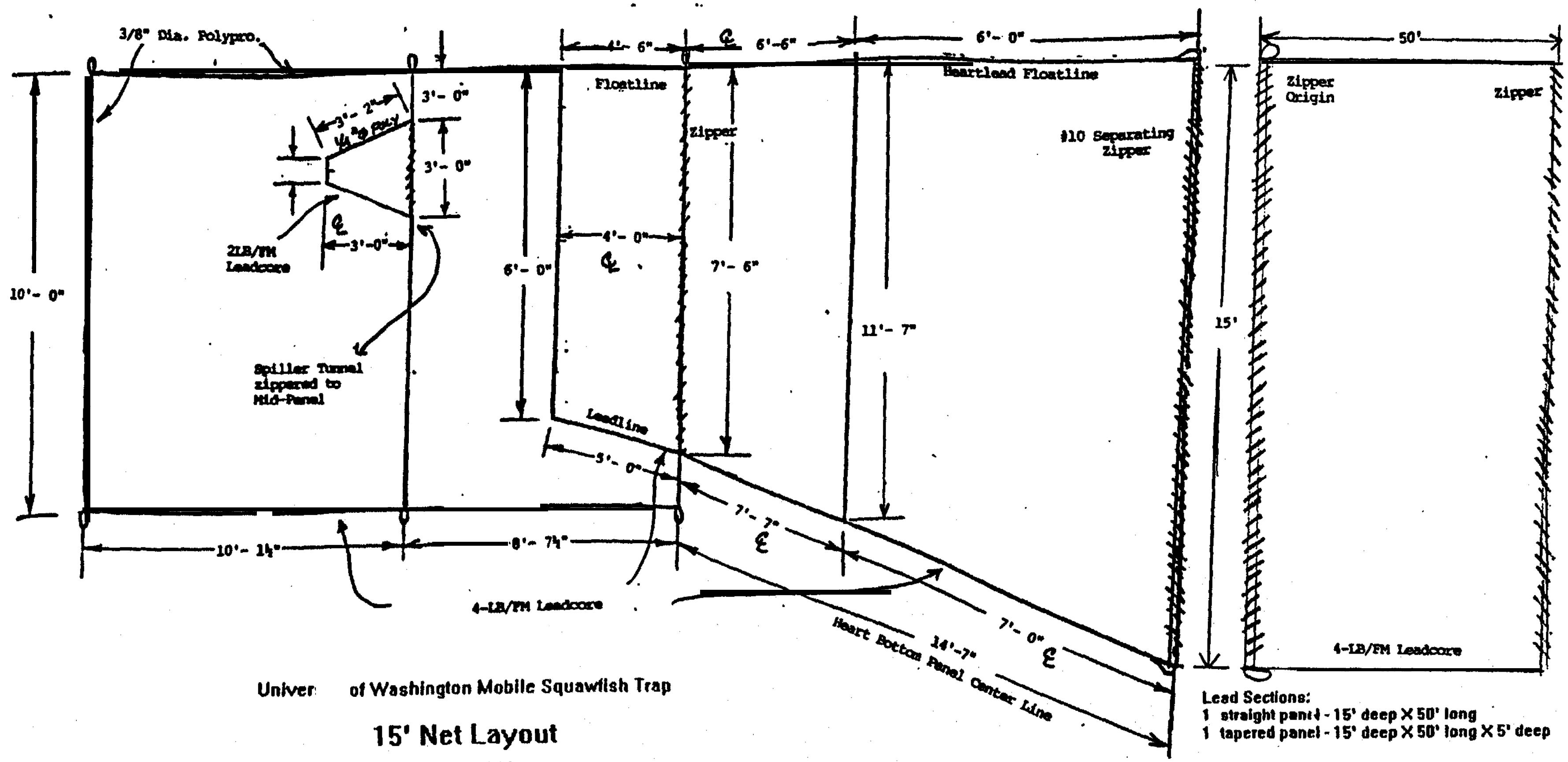
15' Net Layout

(NO SCALE)



Notes:

- 9 and 12 foot spreader bars on heart will not be provided by the vendor
- the pot tunnel spreader bar and spiller tunnel frame will be provided by the vendor



Lead Sections:
1 straight panel - 15' deep X 50' long
1 tapered panel - 15' deep X 50' long X 5' deep

Univer of Washington Mobile Squawfish Trap

15' Net Layout

(NO SCALE)

APPENDXX A-3

Data Forms

Appendix Figure A-3.1.
ODFW floating trap-net catch and effort form.

1993 ODFW FLOATING TRAP NET FISHERY

№ 005001

PAGE ____ OF ____

PERSONNEL ____________

TRAP NUMBER ____________

SITE DESC. ____________

AREA	LOCATION MILE	LOCATION ¼	START MO	START DAY	START TIME	STOP MO	STOP DAY	STOP TIME	DEPTH (ft)	LEAD LENGTH (ft)	TEMP °F	SECC (m)

LINE NUMBER	SPECIES	L STAGE	TALLY	COUNT	FORK LENGTH (mm)	DISP	MARK	TAG	COLOR	TAG NUMBER	COMMENTS
1	SQF	S									
2	SQF	L									
3	CRA	0									
4	PM	0									
5	CLM	0									
6	SU	O									
7											
8											
9											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
0											

AREA

1=CLATS.
2=PRTLND
3=BONNVL
4=DALLES
5=LWR JD
6=UPR JD

LOCATION

1=OR shore
2=OR side of island
3=WA side of island
4=WA shore

L(IFE) STAGE

for salmonids:
A=ADULT
J=JACK
U=JUVENILE

for squawfish:
S=SMALL (under 11in.)
L=LARGE (at or over 11 in.)

DISPOSITION

1 =GOOD
2=FAIR
3=POOR
4=DEAD

COLOR

O-NO INFO W=WHITE
E=ORANGE A=GRAY
Y=YELLOW N=BROWN
R=RED L=LILAC
B=BLUE C=CLEAR
P=PINK G=GREEN

SPECIES

SQF=squawfish
CRA=crappie
PM =peamouth chub
CLM=chiselmouth
SU =sucker
SUN=sunfish

BSU=bridgelip sucker
PK =pumpkinseed sunfish
LAM=lamprey
YP =yellow perch
SH =shad

RB =rainbow trout
CC =channel catfish
B =bullhead
SCU=sculpin
F =flounder

LB =largemouth bass
SB =smallmouth bass
CRP=carp
WF =whitefish
WSG=wht sturgeon

CH =chinook salmon
CO =coho salmon
SS =sockeye salmon
ST =steelhead
SLD=salmonid

Appendix Figure A-3.2.
Columbia River treaty tribes catch and effort form.

OREGON DEPARTMENT OF FISH AND WILDLIFE and COLUMBIA RIVER TREATY TRIBES
1993 Floating Trap Net Fishery

NO, 001002

PAGE ___ OF ___

AREA	LOCATION MILE	¼	START MO	START DAY	START TIME	STOP MO	STOP DAY	STOP TIME	LEAD LENGTH (ft)

PERSONNEL ____________ TRAP # ______

SITE DESCRIPTION ____________

COMMENTS

LINE NUMBER	I	L 8	TALLY	COUNT	DISP	MARK	TAG	COLOR	TAG NUMBER	COMMENTS
1	SQF	S								
2	SQF	L								
3	CRA	0								
4	PM	0								
5	CLM	0								
6	SU	0								
7										
8										
9										
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										
0										

AREA
1=CLATS.
2=PRTLND
3=BONNVL
4=DALLES
5=LWR JD
6=UPR JD

LOCATION
1=OR shore
2=OR side of island
3=WA side of island
4=WA shore

L(IFE) STAGE
for salmonids:
A=ADULT
J=JACK
U=JUVENILE
for squawfish:
S=SMALL (under 11in.)
L=LARGE (at or over 11 in.)

DISPOSITION
1 =GOOD
2=FAIR
3=POOR
4=DEAD

COLOR
O=NO INFO W=WHITE
E=ORANGE A-GRAY
Y=YELLOW N=BROWN
R=RED L=LI LAC
B=BLUE C=CLEAR
P=PINK G=GREEN

SPECIES

SQF=squawfish
CRA=crappie
PM =peamouth chub
CLM=chiselmouth
SU =sucker
SUN=sunfish

BSU=bridgelip sucker
PK =pumpkinseed sunfish
LAM=lamprey
YP =yellow perch
SH =shad

RB =rainbow trout
CC =channel catfish
B =bullhead
SCU=sculpin
F =flounder

LB =largemouth bass
SB =smallmouth bass
CRP=carp
WF =whitefish
WSG=wht sturgeon

CH =chinook salmon
CO =coho salmon
SS =sockeye salmon
ST =steelhead
SLD=salmonid

Appendix Figure A-3.3. Floating trap-net relocation form.

TRAP NET RELOCATION RECORD

PERSONNEL: ____________ PAGE ____ OF ____

TRAP #	AREA	SITE #	START LOCATION MILE	START LOCATION ¼	START MO	START DAY	START TIME	AREA	SITE #	STOP LOCATION MILE	STOP LOCATION ¼	STOP MO	STOP DAY	STOP TIME
			.							.				

SITE DESC. START ____________

SITE DESC. STOP ____________

COMMENTS: ____________

TRAP #	AREA	SITE #	START LOCATION MILE	START LOCATION ¼	START MO	START DAY	START TIME	AREA	SITE #	STOP LOCATION MILE	STOP LOCATION ¼	STOP MO	STOP DAY	STOP TIME
			.							.				

SITE DESC. START ____________

SITE DESC. STOP ____________

COMMENTS: ____________

TRAP #	AREA	SITE #	START LOCATION MILE	START LOCATION ¼	START MO	START DAY	START TIME	AREA	SITE #	STOP LOCATION MILE	STOP LOCATION ¼	STOP MO	STOP DAY	STOP TIME
			.							.				

SITE DESC. START ____________

SITE DESC. STOP ____________

COMMENTS ____________

TRAP #	AREA	SITE #	START LOCATION MILE	START LOCATION ¼	START MO	START DAY	START TIME	AREA	SITE #	STOP LOCATION MILE	STOP LOCATION ¼	STOP MO	STOP DAY	STOP TIME
			.							.				

SITE DESC. START ____________

SITE DESC. STOP ____________

COMMENTS: ____________

APPENDIX A-4

Result Tables

Appendix Table A-4.1. **Effort in Number of Sets (N) and Soak Time (Hours), Mean Soak Time per Set (Mean), and Standard Deviation (STD) by Area and Week**

	AREA															
	1				2				3				4			
WEEK	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD
1	8	84.33	10.54	10.02	20	53.45	2.67	0.33					6	21 03	3 51	0 99
2	33	37.27	1.13	5.86	42	114.62	2.73	0.34	3	9.02	3.01	0.01	.		.	.
3	40	108.32	2.71	1.04	43	91.05	2.12	3.67	16	46.73	2.92	0.18	.		.	.
4	39	113.67	2.91	0.89	47	131.83	2.80	0.65	16	23.37	1.46	5.99	.		.	.
5	36	123.32	3.43	1.36	58	160.95	2.78	0.88	9	28.50	3.17	0.33	.		.	.
6	38	141.42	3.72	2.03	64	126.43	1.98	4.24	9	26.35	2.93	0.13	.		.	.
7	56	183.92	3.28	1.02	58	152.42	2.63	0.60	21	58.27	2.77	0.33	14	42.28	3.02	0.75
8	63	245.53	3.90	4.21	60	163.33	2.72	0.52	24	71.45	2.98	0.41	24	73.18	3.05	0.32
9	59	200.48	3.40	0.98	58	158.10	2.73	0.55	82	254.42	3.10	0.45	22	74.18	3.37	0.39
10	7	19.58	2.80	0.42	24	64.53	2.69	0.56	40	123.57	3.09	0.40	17	74.43	4.38	5.70
ALL	379	1257.83	3.32	3.23	474	1216.72	2.57	1.99	220	641.67	2.92	1.67	83	285.12	3.44	2.61

Table A-2. Continued

	AREA															
	5				6				7				ALL			
WEEK	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD
1													34	158.82	4.67	5.70
2	13	36.12	2.78	0.50									91	197.02	2.17	3.59
3	8	17.37	2.17	0.77	7	18.03	2.58	0.36	3	3.62	1.21	1.56	117	285.12	2.44	2.34
4	2	5.07	2.53	0.45	11	29.50	2.68	0.54					115	303.43	2.64	2.33
5	12	33.57	2.80	0.25	17	43.02	2.53	0.43					132	389.35	2.95	0.98
6	16	45.18	2.82	0.30	20	53.78	2.69	0.45					147	393.17	2.67	3.06
7	2	5.70	2.85	0.00	33	100.65	3.05	0.77					184	543.23	2.95	0.81
8	.	.	.		34	93.97	2.76	0.49					205	647.47	3.16	2.41
9	.	.	.		37	105.87	2.86	0.43					258	793.05	3.07	0.67
10	.	.	.		21	58.15	2.77	0.50					109	340.27	3.12	2.31
ALL	53	143.00	2.70	0.48	180	502.97	2.79	0.55	3	3.63	1.21	1.56	1392	4050.92	2.91	2.27

Appendix Table A-4.2. Catch per unit of effort (CPUE) for northern squawfish and salmonids by crew, area, and **week.**

			Effort		CPUE											
					Northern Squawfish						Salmonids					
					¢11"			All			Adults&Jacks			All		
Crew	Area	Week	Sets (S)	Hours (H)	#	/S	/H	#	/S	/H	#	/S	/H	#	/S	/H
CTUIR	6	5	17	43.02	9	0.5	0.21	62	3.6	1.44	70	4.1	1.63	75	4.4	1.74
		6	20	53.78	23	1.2	0.43	109	5.5	2.03	15	0.8	0.28	16	0.8	0.30
		7	33	100.65	76	2.3	0.76	177	5.4	1.76	12	0.4	0.12	29	0.9	0.29
		8	34	93.97	2	0.1	0.02	61	1.8	0.65	10	0.3	0.11	15	0.4	0.16
		9	37	105.87	38	1.0	0.36	186	5.0	1.76	8	0.2	0.08	22	0.6	0.21
		10	21	58.15	28	1.3	0.48	218	10.4	3.75	1	0.0	0.02	9	0.4	0.15
	All		162	455.44	176	1.0	0.38	813	5.3	1.90	116	1.0	0.37	166	1.3	0.48
		2	3	9.02	1	0.3	0.11	32	10.7	3.55	3	1.0	0.33	7	2.3	0.78
CTWSRO	3	3	16	46.73	5	0.3	0.11	160	10.0	3.42	4	0.3	0.09	10	0.6	0.21
		4	16	23.37	8	0.5	0.34	96	6.0	4.11	2	0.1	0.09	23	1.4	0.98
		5	9	28.50	5	0.6	0.18	190	21.1	6.67	1	0.1	0.04	1	0.1	0.04
		All	44	107.62	19	0.4	0.18	478	11.9	4.44	10	0.4	0.13	41	1.1	0.50
	4	1	6	21.03	1	0.2	0.01	18	3.0	0.86	0	0.0	0.00	2	0.3	0.10
	All		50	128.65	20	0.2	0.10	496	7.5	2.65	10	0.2	0.07	43	0.7	0.30
		7	14	42.28												
NPITI	4	8	24	73.18	25	1.8	0.04	58	4.1	1.37	3 0	0.2 0.0	0.07 0.00	15 3	1.1 0.1	0.35 0.04
		9	22	74.18	45	2.0	0.03	89	4.0	1.20		0.0	0.00		0.0	0.00
		10	17	74.43	3	0.2	0.00	52	3.1	0.70		0.0	0.00		0.0	0.00
		All	77	264.07	104	1.3	0.02	255	3.4	1.01	3	0.1	0.02	18	0.3	0.10
		2	13	36.12		0.0	0.00	4	0.3	0.11	2	0.2	0.06	48	3.7	1.33
	5	3	8	17.37	2	0.3	0.01	3	0.4	0.17	1	0.1	0.06	10	1.3	0.58
		4	2	5.07	1	0.5	0.10	3	1.5	0.59	0	0.0	0.00	4	2.0	0.79
		5	12	33.57	1	0.1	0.00	2	0.2	0.06	2	0.2	0.06	5	0.4	0.15
		6	16	45.18	8	0.5	0.01	17	1.1	0.38	1	0.1	0.02	31	1.9	0.69
		7	2	5.70	1	0.5	0.09	1	0.5	0.18	1	0.5	0.18	5	2.5	0.88
		All	53	143.01	13	0.3	0.04	30	0.7	0.25	7	0.2	0.06	103	2.0	0.73
		3	7	18.03		0.0	0.00	13	1.9	0.72	1	0.1	0.06	9	1.3	0.50
	6	4	11	29.50	1	0.1	0.00	27	2.5	0.92	7	0.6	0.24	16	1.5	0.54
		All	18	47.53	1	0.0	0.00	40	2.2	0.82	8	0.4	0.15	25	1.4	0.52

Appendix Table A-4.2. Continued.

Crew	Area	Week	Effort: Sets (S)	Effort: Hours (H)	Northern Squawfish ¢11" #	¢11" /S	¢11" /H	Northern Squawfish All #	All /S	All /H	Salmonids Adults&Jacks #	Adults&Jacks /S	Adults&Jacks /H	Salmonids All #	All /S	All /H
NPITI	7	3	3	3.62		0.0	0.00	1	0.3	0.28		0.0	0.00		0.0	0.00
	All		151	458.23	118	0.4	0.01	326	1.6	0.59	18	0.2	0.06	146	0.9	0.34
		1														
ODFW-A	1	2	8	84.33	2	0.3	0.00	12	1.5	0.14	2	0.3	0.02	21	2.6	0.25
			33	37.27	9	0.3	0.01	72	2.2	1.93	19	0.6	0.51	60	1.8	1.61
		3														
		5	40 39	108.32 113.67	48 41	1.0 1.2	0.01 0.01	414 294	10.6 7.4	3.64 2.71	86 32	2.2 0.8	0.76 0.30	101 79	2.0 2.6	0.73 0.89
		6	36 38	141.42 123.32	99 96	2.5 2.8	0.02 0.02	405 386	10.7 10.7	3.13 2.86	114 52	3.2 1.4	0.92 0.37	126 67	3.5 1.8	0.47 1.02
		7														
		8	56 63	245.53 183.92	135 80	2.4 1.3	0.01 0.01	726 509	13.0 8.1	3.95 2.07	55 62	0.9 1.1	0.34 0.22	124 133	2.2 2.1	0.67 0.54
		9														
		10	59 7	200.48 19.58	108 9	1.3 1.8	0.01 0.07	685 44	11.6 6.3	3.42 2.25	29 3	0.4 0.5	0.15 0.14	77 6	0.9 1.3	0.38 0.31
	All		379	1257.84	627	1.4	0.02	3547	8.2	2.61	454	1.1	0.37	794	2.1	0.69
ODFW-B	2	1	20	53.45	7	0.4	0.01	24	1.2	0.45	3	0.2	0.06	114	5.7	2.13
		2	42	114.62	6	0.1	0.00	61	1.5	0.53	15	0.4	0.13	119	2.8	1.04
		3	43	91.05	14	0.3	0.00	77	1.8	0.85	43	1.0	0.47	69	1.6	0.76
		4	47	131.83	53	1.1	0.01	155	3.3	1.18	57	1.2	0.43	103	2.2	0.78
		5	58	160.95	124	2.1	0.01	546	9.4	3.39	95	1.6	0.59	145	2.5	0.90
		6	64	126.43	94	1.5	0.01	395	6.2	3.12	22	0.3	0.17	59	0.9	0.47
		7	58	152.42	105	1.8	0.01	534	9.2	3.50	106	1.8	0.70	134	2.3	0.88
		8	60	163.33	59	1.0	0.01	409	6.8	2.50	19	0.3	0.12	260	4.3	1.59
		9	58	158.10	87	1.5	0.01	425	7.3	2.69	18	0.3	0.11	140	2.4	0.89
		10	24	64.53	28	1.2	0.02	104	4.3	1.61	3	0.1	0.05	54	2.3	0.84
	All		474	1216.71	577	1.1	0.01	2730	5.1	1.98	381	0.7	0.28	1197	2.7	1.03
		6														
ODFW-C	3	7	9	26.35	5	0.6	0.02	160	17.8	6.07	21	2.3	0.80	53	5.9	2.01
			21	58.27	18	0.9	0.01	241	11.5	4.14	18	0.9	0.31	33	1.6	0.57
		8														
		9	24 82	254.42 71.45	31 75	1.3 0.9	0.02 0.00	1244 378	15.8 15.2	5.29 4.89	7 6	0.3 0.1	0.10 0.02	39 29	1.2 0.5	0.41 0.15
		10	40	123.57	41	1.0	0.01	505	12.6	4.09	5	0.1	0.04	16	0.4	0.13
	All		176	534.06	170	0.9	0.01	2528	14.6	4.89	57	0.7	0.25	170	1.9	0.65
ALL		ALL	1392	4050.93	1688	0.8	0.09	10440	7.0	2.44	1036	0.6	0.23	2516	1.6	0.58

Appendix Table A-4.3. Total catch by family and species.

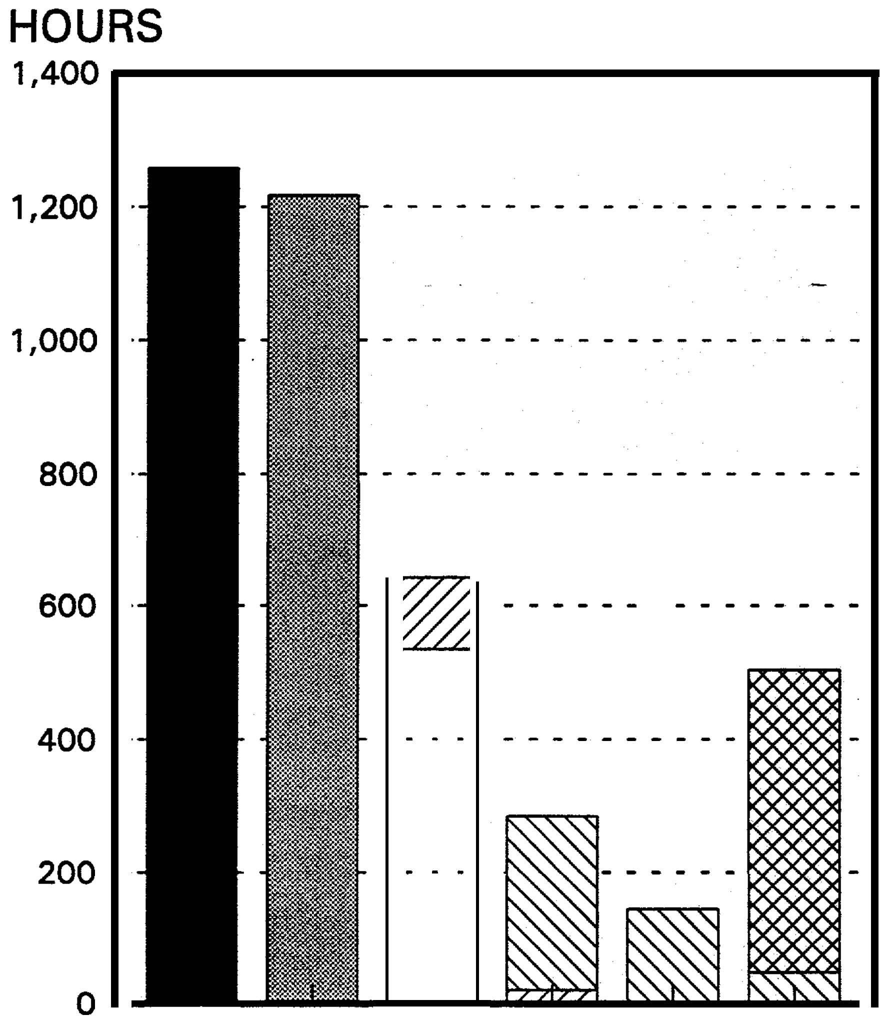
Family	Common Name	Scientific Name	Count	Subtotal	% Tot.Catch
Petromyzontidae (Lampreys)					
	Lamprey spp.		41		
				41	0.09
Acipenseridae (Sturgeons)					
	White Sturgeon	Acipenser transmontanus	8		
				8	0.02
Clupeidae (Herrings)					
	American Shad	Alosa sapidissima	1,500		
				1,500	3.27
Salmonidae (Salmons, Trouts, etc.)					
	Salmonid spp.		1,426		
	Chinook Salmon	Oncorhynchus tshawytscha	41		
	Sockeye Salmon	Oncorhynchus nerka	319		
	Steelhead	Oncorhynchus mykiss	730		
				2,516	5.49
Cyprinidae (Minnows)					
	Carp	Cyprinus carpio	147		
	Goldfish	Carassius auratus	6		
	Chiselmouth	Acrocheilus alutaceus	2,766		
	Redside Shiner	Richardsonius balteatus	3,234		
	N. Squawfish	Ptychocheilus oregonensis	10,440		
	Peamouth	Mylocheilus caurinus	17,571		
				34,164	74.59
Catostomidea (Suckers)					
	Sucker spp.		2,593		
	Largescale S.	Catostomus macrocheilus	5		
	Bridgeliop S.	Catostomus columbianus	52		
				2,650	5.72
Ictaluridae (Catfishes)					
	Channel Catfish	Ictalurus punctatus	74		
	Bullhead spp.		438		
	Yellow Bullhead	Ictalurus matalis	6		
	Brown Bullhead	Ictalurus nebulosus	15		
				533	1.16
Gasterosteidea (Sticklebacks)					
	Three-Spine Stickleback	Gasterosteus aculeatus	32		
				32	0.07
Percopsidea (Troutperches)					
	Sandroller	Percopsis transmontana	210		
				210	0.46

Appendix Table A-4.3. Continued.

Family	Common Name	Scientific Name	Count	Subtotal	% Tot.Catch
Centrarchidea (Sunfishes)					
	Sunfish spp.		416		
	Largemouth Bass	Micropterus salmoides	19		
	Smallmouth Bass	Micropterus dolomieui	45		
	Crappie spp.		1,508		
	Black Crappie	Pomoxis nigromaculatus	5		
	White Crappie	Pomoxis annularis	2		
	Warmouth Bass	Lepomis gulosis	1		
	Green Sunfish	Lepomis cyanellus	1		
	Bluegill	Lepomis macrochirus	182		
	Pumkinseed	Lepomis gibbosus	234		
				2,413	5.27
Percidae (Perches)					
	Walleye	Stizostedion vitreum vitreum	13		
	Yellow Perch	Perca flavescens	46		
				59	0.13
Cottidae (Sculpins)					
	Sculpin spp.		1,127		
				1,127	2.46
Pleuronectidea (Flounders)					
	Starry Flounder	Platichthys stellatus	29		
				29	0.06
Other					
	Unidentified Fish		1		
	Crayfish		520		
				521	1.14
			TOTAL	45,803	100.00

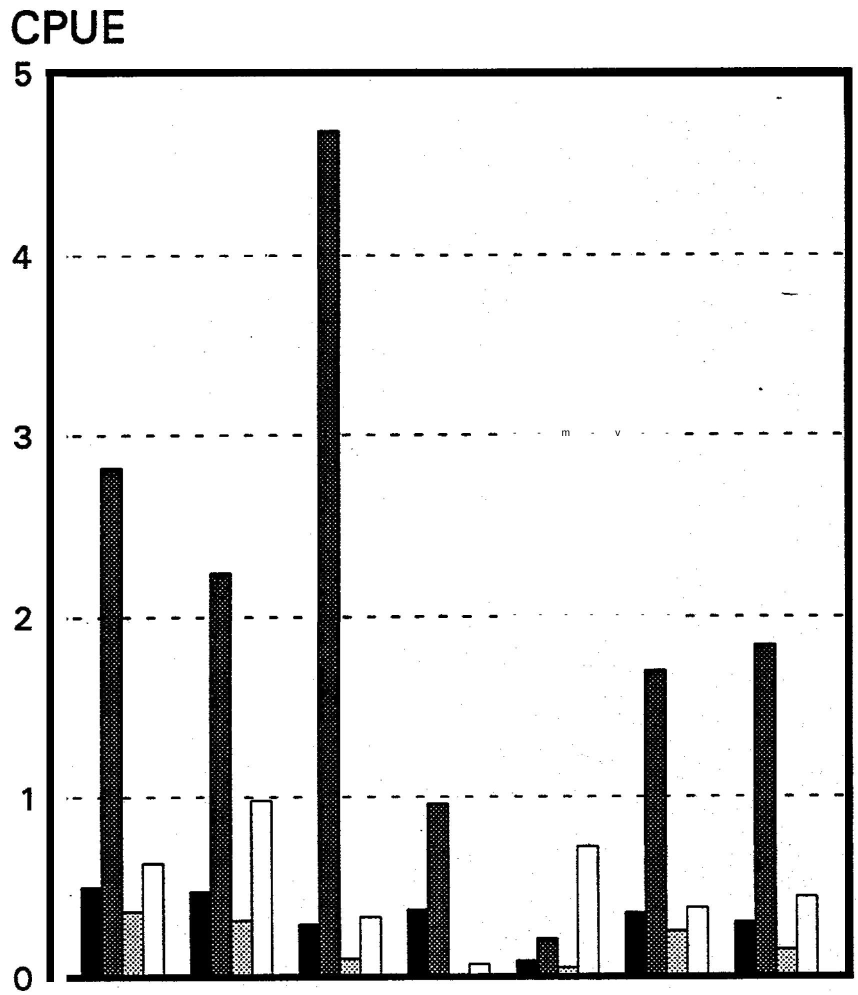
APPENDIX A-5

Result Figures



AREA	1	2	3	4	5	6
ODFW-A	1,257.83					
ODFW-B		1,216.72				
ODFW-C			534.05			
CTWSRO			107.62	21.03		
NPITI				264.08	143.00	47.53
CTUIR						455.43

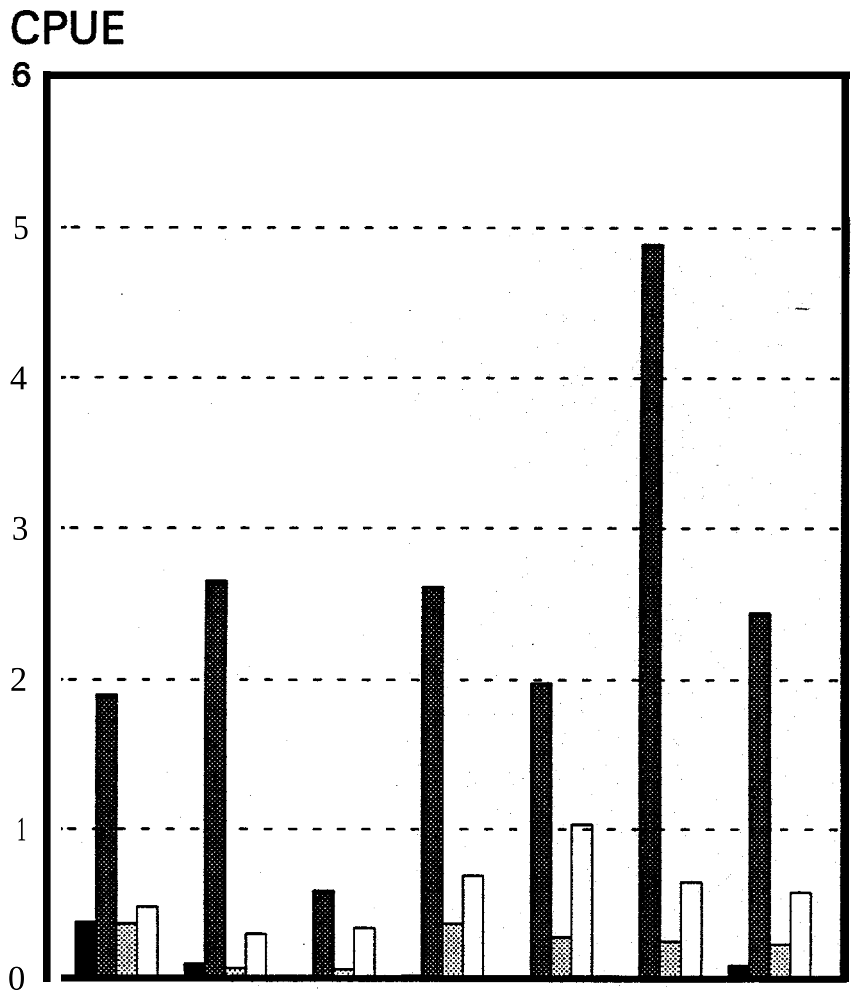
Appendix Figure A-5.1. Effort in hours by area and fishing crew.



AREA	1	2	3	4	5	6	ALL
NSQF(>11")	0.50	0.47	0.29	0.37	0.09	0.35	0.30
NSQF(All)	2.82	2.24	4.68	0.96	0.21	1.70	1.84
SALM(Adult*)	0.36	0.31	0.10	0.01	0.05	0.25	0.15
SALM(All)	0.63	0.98	0.33	0.07	0.72	0.38	0.44

* Jacks included

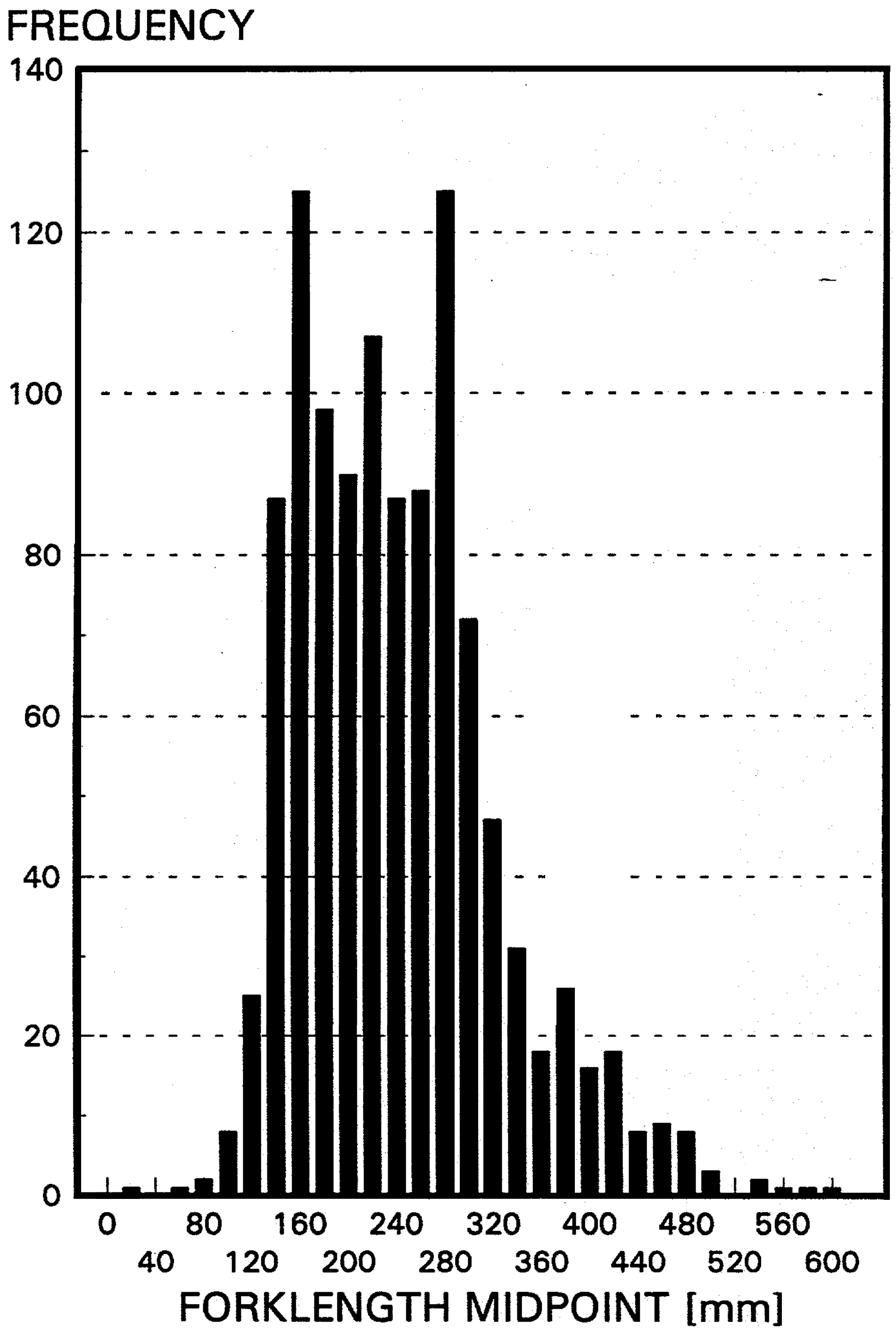
Appendix Figure A-5.2. Catch per unit of effort (CPUE) for northern squawfish and salmonids by area.



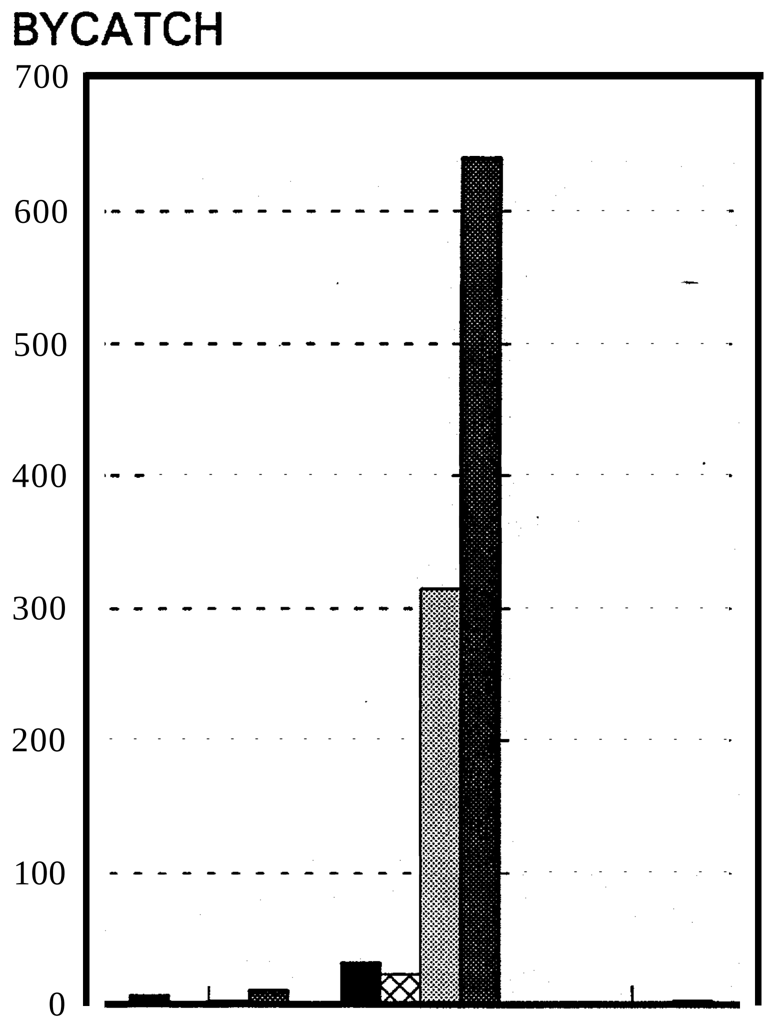
CREW	CTUIR	CTWSRO	NPITI	ODFW-A	ODFW-B	ODFW-C	ALL
NSQF(>11")	0.38	0.10	0.01	0.02	0.01	0.01	0.08
NSQF(All)	1.90	2.66	0.59	2.61	1.98	4.09	2.44
SALM(Adult*)	0.37	0.07	0.06	0.37	0.28	0.26	0.23
SALM(All)	0.48	0.30	0.34	0.09	1.03	0.66	0.58

* Jacks included

Appendix Figure A-5.3. Catch per unit of effort (CPUE) for northern squawfish and salmonids by fishing crew.

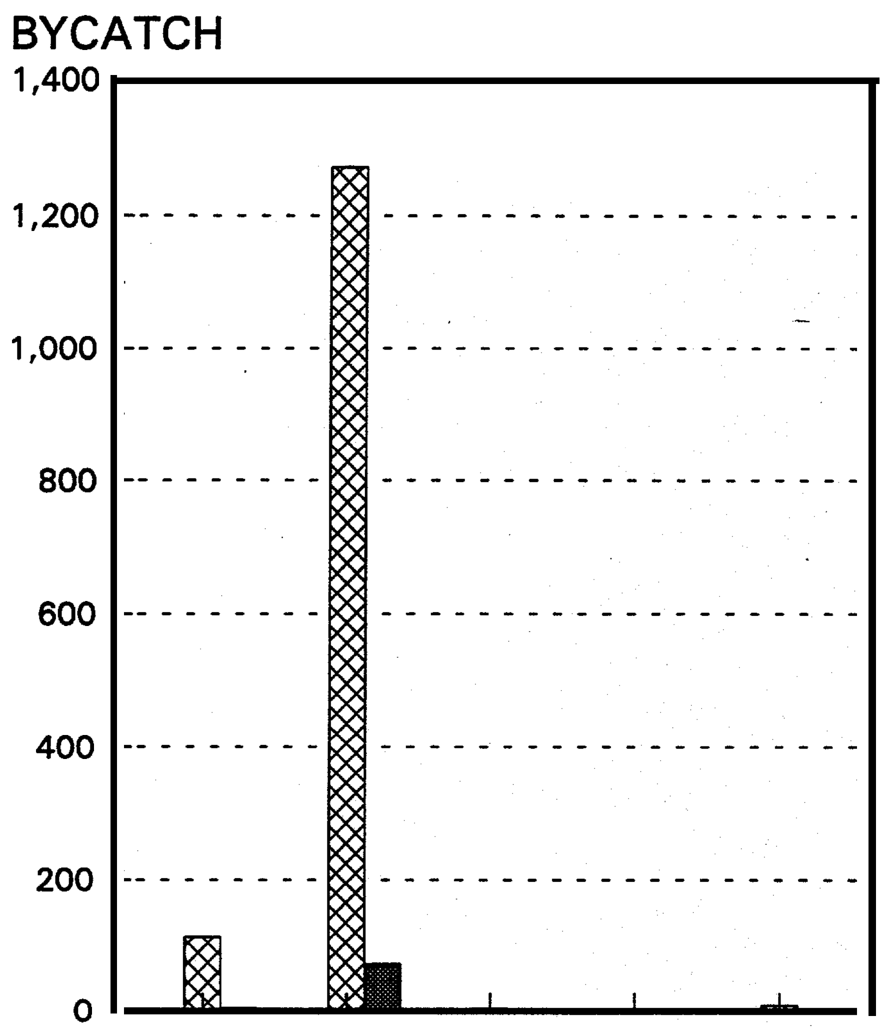


Appendix Figure A-5.4. Northern squawfish fork length frequency.



CONDITION	Not Recorded	Good	Fair
Chinook	7	32	
Unidentified	2	23	
Sockeye	3	315	1
Steelhead	11	639	3

Appendix Figure A-5.5. Release condition of adult and jack **salmonid bycatch.**



CONDITION	Not Recorded	Good	Fair	Poor	Dead
Chinook		2			
Unidentified	113	1,271	4	3	9
Steelhead	5	72			

Appendix Figure A-5.6. Release condition of juvenile salmonid bycatch.

REPORT B

Evaluation of the Northern Squawfish Sport-Reward Fishery in the Columbia and Snake Rivers

Prepared by

Daniel C. Klaybor
Craig C. Burley
Scott S. Smith
Eric N. Mattson
Eric C. Winther
Paul E. DuCommun
Heather R. Bartlett
Stacie L.. Kelsey

Washington Department of Fish and Wildlife
600 Capitol Way N., Olympia, WA 98501-1091

1993 Annual Report

CONTENTS

Page

ACKNOWLEDGMENTS

This project was funded by the Bonneville Power Administration, William Maslen, Project Manager (Contract DE-B179-90BP07084). We thank Chuck Willis, S.P. Cramer and Associates Inc.; David Ward and his staff, Christine Mallette and her staff, Oregon Department of Fish and Wildlife; Susan Hanna and her staff, Oregon State University; Stephen B. Mathews and his staff, University of Washington; Lewis J. (Sam) Bledsoe, Computer Sciences Corporation; Roy Beaty and his staff, Columbia River Inter-Tribal Fish Commission; Dick Ledgerwood and his staff, National Marine Fisheries Service; and Pam Kahut and her staff, Pacific States Marine Fisheries Commission, for their cooperation and coordination.

We thank the U.S. Army Corps of Engineers for the use of its project facilities at Hamilton Island Fort Rains outlook, LePage Park, Hood Park, and the Greenbelt Boat Ramp. We thank the Washington Department of Transportation for the use of its facilities at the Vemita Rest Area. We thank the City of Rainier for the use of the Rainier Boat Ramp, the City of Richland for the use of Columbia Point Park, the Port of the Dalles for the use of the Dalles Boat Basin, the Port of Klickitat for the use of Bingen Marina, the Port of Cathlamet for the use of Cathlamet Marina, the Port of Kalama for the use of Kalama Marina, the Port of Cascade Locks for the use of Cascade Locks Marina, the Port of Umatilla for the use of Umatilla Boat Ramp, the Port of Whitman County for the use of Boyer Park, the Port of Columbia County for the use of Lyons Ferry Marina, the Port of Camas/Washougal for the use of the Camas/Washougal Boat Ramp, and Multnomah County Parks Department for the use of its facilities at M.J. Gleason Park. We thank Sheila Cannon for the use of The Fishery at Covert's Landing.

We thank Jeff Adams, John Aleckson, Jack Anderson, Liane Anderson, Shawn Anderson, Peter Bergman, Lars Bergstrom, Tony Blaine, Jason Bradley, John Brady, Kathleen Byrd, John P. Brown, Scott Clark, Kathy Clawson, Mike Dawkins, Tom Dobbs, Angela Duling, Scott Fielding, Beverly Frantum, Kristi Gadwa, Bryce Glaser, Barbara Griggs, Evelyn Haase, Carrie Holmes, Maria Holmes, John Hone, Kevin Hooker, Kurt Hubbard, Lyle Jansma, Tyson Jerald, Mark Kramer, Shawna Lomen, John Maher, Matthew Marshall, Steve Martin, Merl May, Derrick Meaghers, Eric Meyer, Linda Moore, Robert Morgan, Kathleen Moyer, Bryan Murphie, Travis Nelson, Brian Pederson, Bob Phelps, Bill Rogers, Jeanne Pogue, Dean Selby, Steve Skorheim, Eric Schneider, Eric Soder, John Songster, Joe F. Steele, Shannon Stein, Howard Takata, Mark Thompson, Vicky Troastle, David Van Schoiack, Mark Wachtal, Russ Waitt, Rick Watson, Merrilynn Weeks, and Melvin Whittle for their work operating the sport-reward fishery registration stations.

We thank Carolyn Crandall, Conrad Dickson, Randy Drew, John Randall, Cynthia Rief, and Nickie Royse for computer data entry and verification of volumes of documents. We thank Dr. John Tarnai from Washington State University and Dr. Dale Everson from the University of Idaho for their input to the phone survey analysis. We thank Daylene Cahill, and Diane DuCommun for their numerous phone survey interviews and data entry. We give special thanks to Dennis Gilliland for overseeing data entry integrity and quality control along with computer programming and data base queries for analyses. We give special thanks to Stacie Kelsey for her organization and verification of weekly field data summaries along with scale and tag collection information. We give thanks to Janice Orr for her contributions in completing the annual report.

ABSTRACT

We report progress of the Northern Squawfish ***(Ptychocheilus oregonensis)*** **Sport-**Reward Fishery in the Columbia and Snake River basins for the period of May 3-September 12, 1993. Program parameters involved (1) registering anglers to participate; (2) issuing pay voucher/questionnaires to successful anglers; (3) collecting biological data on northern squawfish and other fish species turned in at the registration stations; (4) conducting a phone survey to assess non-returning anglers for trip specific information; (5) conducting a comparison study utilizing a computerized data collection unit verses manual data collecting; and (6) reporting the overall dynamics of the fishery.

A total of 104,536 northern squawfish were harvested and turned in to registration stations for reward payment ($3 per northern squawfish 11 inches or greater). A total of 34,879 registered angler days were spent fishing for northern squawfish. Of the total registered anglers, 43 % (15,106) returned to the registration stations for processing. An additional 7,786 northern squawfish under 11 inches were turned in (no payment was issued for northern squawfish less than 11 inches).

The 1993 season harvest of northern squawfish eligible for payment was 44% lower than in 1992 and 34 % lower than in 1991. Participation (effort) was 60% lower than in 1992 and 48% lower than in 1991. The catch per unit effort (CPUE, fish/angler day) in 1993 (2.46) was not significantly different **(P<0,0905)** than the 1991 CPUE **(2.37),** but the CPUE for 1992 (2.74) was significantly different **(P<0.0001)** from 1991 and 1993.

Fork lengths were measured from 75,219 northern squawfish of which 68,797 had a fork length measurement greater or equal to 250 mm (approximately 11 inches total length). The overall mean fork length of northern squawfish greater or equal to 250 mm was 334.7 mm (S.D. 61.6). We observed a statistically significant decrease in mean fork length from 1991 to 1993 for all reservoirs combined.

A total of 2,100 fish other than northern squawfish were brought to the registration stations from registered anglers for data collection (2.0% of all fish species returned). Peamouth chub ***(Mylocheilus caurinus)*** accounted for the highest reported harvest (702) of the game fish species. A total of 493 smallmouth bass ***(Micropterus dolomieui),*** 202 channel catfish ***(Ictalurus punctatus),*** and 12 1 walleye ***(Stizostedion vitreum)*** were observed at the registration stations.

The comparison study to assess the use of a computerized data collection unit verses manual data collection concluded that the computerized data entry system was significantly faster than manual data processing for the exit interview and biological data collection process, but computerized data entry was not significantly faster than manual'data processing for the registration process. Biological data collection could be entered approximately twice as fast using the computerized system.

A phone survey was used to address fishing trip information for non-returning anglers. Contacts were made to 1,744 (8.8%) of the 19,758 non-returning registered anglers. A recall bias study was conducted for returning anglers to estimate the accuracy of anglers' responses to phone survey questions. The recall bias study found anglers' average responses to questions concerning past fishing trips to be accurate. Marked differences were observed in the proportions of other fish species caught between the phone survey data and actual returning angler data.

INTRODUCTION

Predation on outmigrating juvenile salmonids ***(Oncorhynchus*** spp.) by northern squawfish (*Ptychocheilus oregonensis*) in the Columbia River Basin has been identified as a major concern of the Columbia Basin Fish and Wildlife Program (NPPC 1987). Predator control of northern squawfish on the Columbia and Snake rivers has developed in recent years to the extent that multiple fisheries now exist that target on the harvest of northern squawfish (Nigro 1990). The goal of the predator control program is to achieve a sustained harvest of 10-20% of the larger northern squawfish in the population (250 mm or longer fork length). This could restructure the population and reduce the impacts of predation on the outmigrating juvenile salmonids by as much as 50% (Rieman and Beamesderfer 1990).

One component of the program is a test fishery, paying the public a reward of $3 for each northern squawfish 11 inches or longer (Burley et al. 1992). The sport-reward test fishery started in 1990 in the John Day Reservoir (Vigg et al. 1990) and expanded to include multiple reservoirs in the Columbia and Snake rivers in 1991 (Burley et al. 1992).

The general objective of this project was to implement the sport-reward fishery for northern squawfish at 18 registration stations on the Washington and Oregon shores in the lower Columbia and Snake rivers from May 3-September 12, 1993. Specific objectives were to register participating anglers in the fishery, issue vouchers for payment to successful anglers, collect biological data on northern squawfish and other fish species caught and turned into the registration stations, and to report on the inseason dynamics of the fishery. Changes in mean fork length of northern squawfish caught in 1991, 1992 and 1993 were compared to determine if the average size of northern squawfish caught was decreasing. The feasibility of using a phone survey to collect information from non-returning registered anglers, and a comparison study between computerized data collection and manual data collection were also tested.

METHODS

Study Area

The sport-reward fishery for northern squawfish was conducted on the Columbia River from the mouth to the boat-restricted zone of Priest Rapids Dam, and on the Snake River from the mouth to the boat-restricted zone of Hells Canyon Dam. Backwaters, sloughs, and up to 400 feet inside the mouth of tributaries along the above mentioned reaches of the Columbia and Snake rivers were also open for harvest of northern squawfish for payment. Eighteen registration stations were located on the lower Columbia and Snake rivers (Figure 1).

A “tailrace” was defined as the section of river immediately below a dam. A “forebay” was defined as the section of river immediately above a dam. A “reservoir” was defined as the section of river from the tailrace of an upstream dam to the forebay of the next dam downstream, except for the section of river below Bonneville Dam, which ranged from the tailrace of Bonneville Dam to the mouth of the Columbia River.

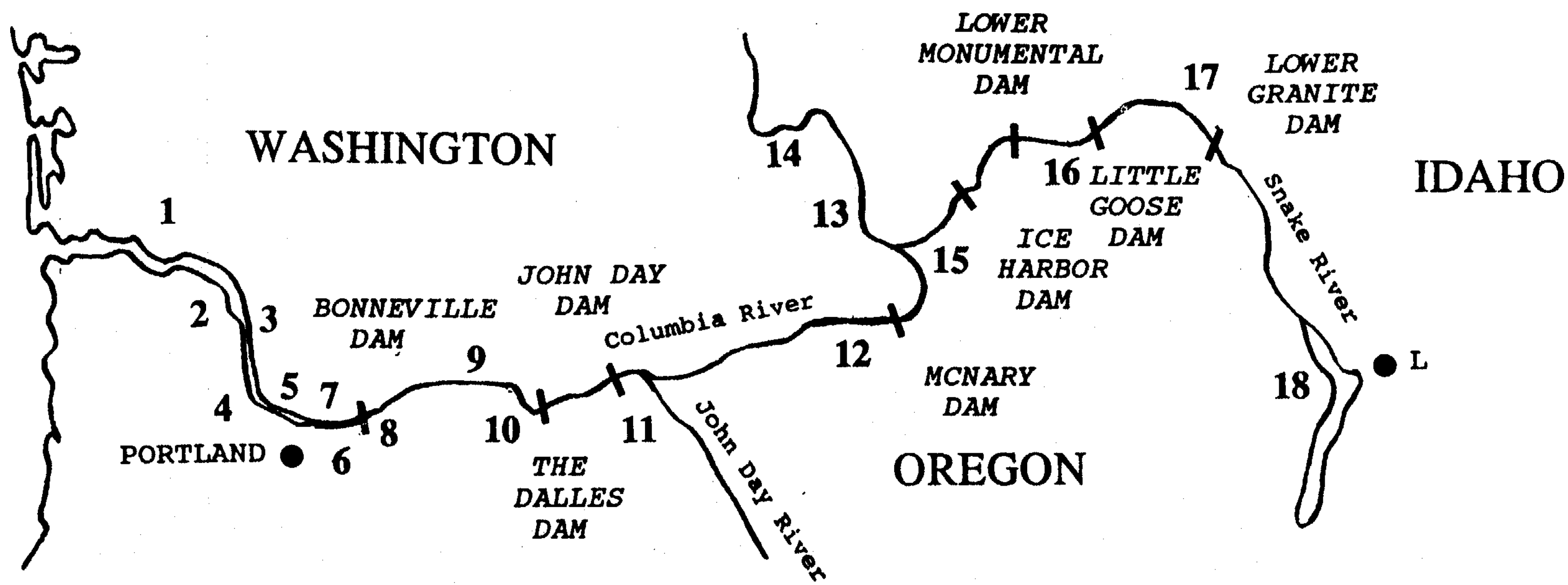
Field Procedures

New state regulations were implemented in 1993 to improve the processing of angler information and to reduce opportunities for fraud. Angler compliance rules were adopted as follows:

A. Each angler must register in person, prior to fishing, at one of the registration stations each fishing day. A fishing day is a 24-hour period from 9:01 p.m. through 9 p.m. of the following day.

B. Each angler, in person, must exchange their eligible northern squawfish for a voucher between the hours 9 a.m. and 9 p.m. at the same registration station where the angler is registered during the same fishing day.

C. To be eligible for a voucher, each northern squawfish must be 11 inches or longer in total length and presented in fresh condition or alive.



1.	Cathlamet (WA)	7.	Hamilton Island (WA)	13.	Columbia Point (WA)
2.	Rainier (OR)	8.	Cascade Locks (OR)	14.	Vernita (WA)
3.	Kalama (WA)	9.	Bingen (WA)	15.	Hood Park (WA)
4.	Gleason (OR)	10.	The Dalles (OR)	16.	Lyons Ferry (WA)
5.	Camas (WA)	11.	LePage (OR)	17.	Boyer Park (WA)
6.	The Fishery (OR)	12.	Umatilla (OR)	18.	Greenbelt (WA)

Figure 1. Location of the Northern Squawfish Sport-Reward Fishery registration stations on the Columbia and Snake rivers during the 1993 field season.

D. Anglers shall provide information regarding their catch as requested by department personnel at the registration site and mail-in survey forms.

E. Anglers shall obtain a Washington, Oregon, or Idaho state fishing license to fish for northern squawfish and must use a single rod, reel and line with up to three hooks with no more than three points.

Several fish species in Washington were classified as game fish in 1993. These included northern squawfish (*Ptychocheilus oregonensis*); peamouth chub (*Mylocheilus caurinus*); bridgelip sucker (*Catostomus columbianus*); largescale sucker (*Catostomus microps*); and longnose sucker (*Catostomus catostomus*).

Registration Interview

Washington Department of Fish and Wildlife (WDFW) technicians were present to register anglers from 9 a.m. to 9 p.m. seven days per week. Anglers could self-register at a registration box near the site between 9:01 p.m. and 8:59 a.m. A short registration form was completed to record information pertinent to the anglers fishing day.

Exit Interview

Upon completion of fishing, anglers were requested to return to the same station where they registered. A WDFW technician retrieved the angler's registration form and conducted the exit interview. All fish turned in were inspected and counted by technicians. This included the number of northern squawfish 11 inches or greater ($3 reward per fish), the number of northern squawfish turned in less than 11 inches, and the number of northern squawfish lost or released. Other fish species harvested were verified and recorded.

The qualifying northern squawfish were totaled and the angler was issued a pay voucher. The technician and angler each signed the pay voucher to verify the number of northern squawfish eligible for the reward. The angler was required to complete the inside questionnaire and mail it to the Pacific States Marine Fisheries Commission (PSMFC) in Portland. Sport-reward payment was funded by the Bonneville Power Administration (BPA).

Biological Data Collection

Fish brought to the registration station by registered anglers were sampled for biological data when time permitted. These data were recorded on the back portion of the original angler registration form. During periods when large numbers of fish were being turned in or people were in line to register or exit, a subsampling regime was conducted.

Biological data collected for northern squawfish catches numbering 30 or fewer consisted of a fork length, weight and scale sample. Complete biological data were then taken on every fifth northern squawfish (fork length, weight, scale sample, and sex determined by opening up the fish). Catches greater than 30 northern squawfish were subsampled for fish species and fork length. Every fifth fish was sampled for species, length, weight, and scales. By dissecting the northern squawfish for sex determination, the fish became a "poor" quality grade due to the body fluids and internal organ exposure. In an effort to increase "food grade" northern squawfish, every 10th fish had species, length, weight, scale, and sex data collected in a 30 plus fish scenario. Other fish species brought to the site were processed for biological data then returned to the angler. Technicians would record biological data on all tagged fish. Complete biological information on all tagged fish was provided to the Oregon Department of Fish and Wildlife (ODFW) on a weekly basis.

Mean fork lengths were compared for statistically significant differences among reservoirs using a general linear model for analysis of variance.

Northern Squawfish Processing

All reward-size northern squawfish were tail clipped to indicate processing by a WDFW technician. Each northern squawfish was graded according to guidelines provided by Oregon State University (OSU) to determine whether a fish would be processed as "food-grade" or "fertilizer-grade" fish. Food-grade fish were placed on ice in insulated coolers marked "good" and fertilizer-grade fish were placed in insulated coolers marked "poor." At the end of each shift, technicians delivered the fish to a designated facility for processing or storage by facility personnel. Empty coolers and ice were picked up by technicians for the next day.

RESULTS

Northern Squawfish Harvest Data

The 1993 overall harvest of northern squawfish eligible for payment (11 inches or longer) was 104,536 fish. Participation (effort) associated with this harvest amounted to 34,879 angler days yielding a systemwide catch per unit effort (CPUE) of 2.46 (fish/angler day). In addition, 7,786 northern squawfish less than 11 inches were returned (no payment was issued for northern squawfish less than 11 inches).

The systemwide mean weekly harvest was 5,506 northern squawfish with a range of 2,566 to 10,381 fish (Figure 2). The mean angler effort by week was 1,836 angler days and ranged from 885 to 2,792 angler day (Figure 2). The mean CPUE was 2.46 fish/angler day with a range of 1.11 to 3.44 fish/angler day by week (Figure 2).

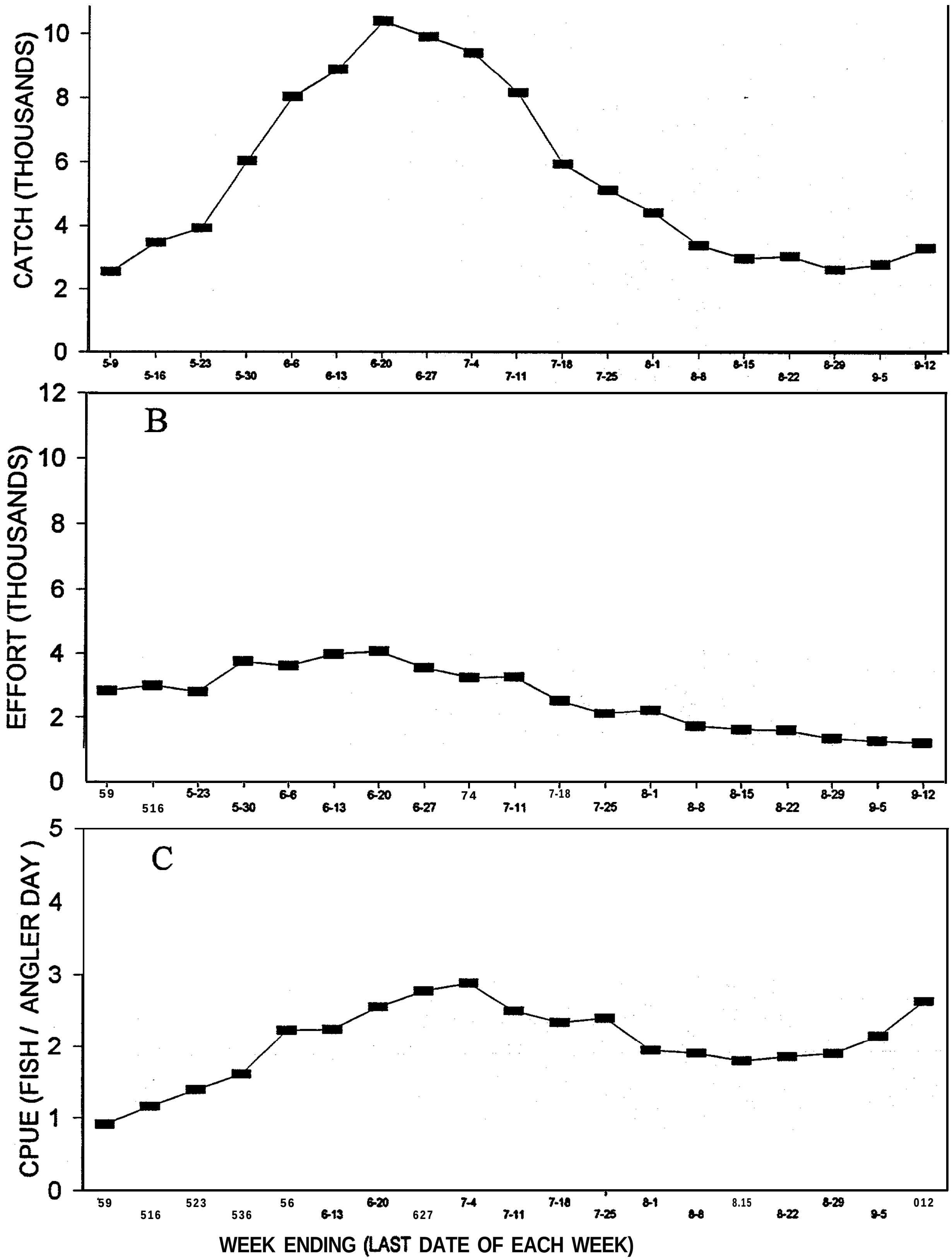


Figure 2. Sport-reward fishery data by week for 1993. A - Northern squawfish catch by week for 1993. B - Effort (angler days) by week for 1993. C - CPUE (fish / angler day) by week for 1993.

Harvest ranged from 1,076 northern squawfish in John Day Reservoir to 48,707 in the Bonneville tailrace (Figure 3). There was no registration station in Ice Harbor Reservoir in 1993, however, the reservoir was open to participation and a harvest of 45 northern squawfish was recorded. Effort in registered returning angler days (fishing location could only be recorded for anglers returning to the stations) ranged from 24 in Ice Harbor Reservoir to 10,838 in Bonneville Tailrace. The average CPUE by reservoir was 5.02 fish/returning angler day. The CPUE ranged from 1.95 fish/returning angler day in John Day Reservoir to 9.04 fish/returning angler day in McNary Reservoir (Figure 3).

All nine reservoirs in 1993 showed a decrease in harvest when compared with 1992 reservoir data. The largest decrease in harvest from 1993 to 1992 was in the Bonneville tailrace (30,689 northern squawfish). Eight of the nine reservoirs showed reduced harvest when compared to the 1991 reservoir data. The largest decrease in harvest from 1993 to 1991 was in The Dalles Reservoir (24,814 northern squawfish). McNary Reservoir was the only reservoir to show an increase in harvest (11,786 northern squawfish) in 1993 compared to 1991.

The mean catch of northern squawfish per registration station was 5,807 fish and ranged from 1,000 fish at Umatilla Boat Ramp to 16,308 fish at The Fishery (Figure 4). The mean effort (angler days) by registration station was 2,779 and ranged from 1,315 angler days at Boyer Park to 4,720 at Greenbelt Boat Ramp (Figure 4). The mean CPUE by registration station was 2.46 fish/angler day and ranged from 0.67 fish/angler day at Umatilla Boat Ramp to 5.39 fish/angler day at The Fishery (Figure 4).

Ten of the 18 registration stations in 1993 were operated in 1991 and 1992. All 10 stations showed decreases in harvest of northern squawfish. The lo-station comparison to 1992 harvest showed LePage Park to have the largest decrease in harvest of 21,498 northern squawfish. The Fishery (Covert's Landing) had the largest decrease in 1993 in comparison to 1991 of 24,366 fish (Table 1).

Northern squawfish catch was highest (27,180 fish) in Fishing Location 10 (Appendix Table B-l), which extends from the tailrace of Bonneville Dam downstream to Reed Island. The catch from Fishing Locations 10 (27,180), 9 (12,604), and 16 (10,334) accounted for approximately 48% of the total catch of northern squawfish eligible for payment (Appendix Tables B l-3). The top one-third, which represented 17 fishing locations, that produced the highest catch ranged from 27.180 to 1,423 northern squawfish and accounted for approximately 88% of the total catch of northern squawfish eligible for payment. Effort was also highest in Fishing Locations 10 (4,547), 9 (3,502), and 16 (1,477; Appendix Tables B 4-6), but CPUE was highest in Fishing Locations 31 (23.4), 30 (14.79) and 32 (11.03; Appendix Tables B 7-9).

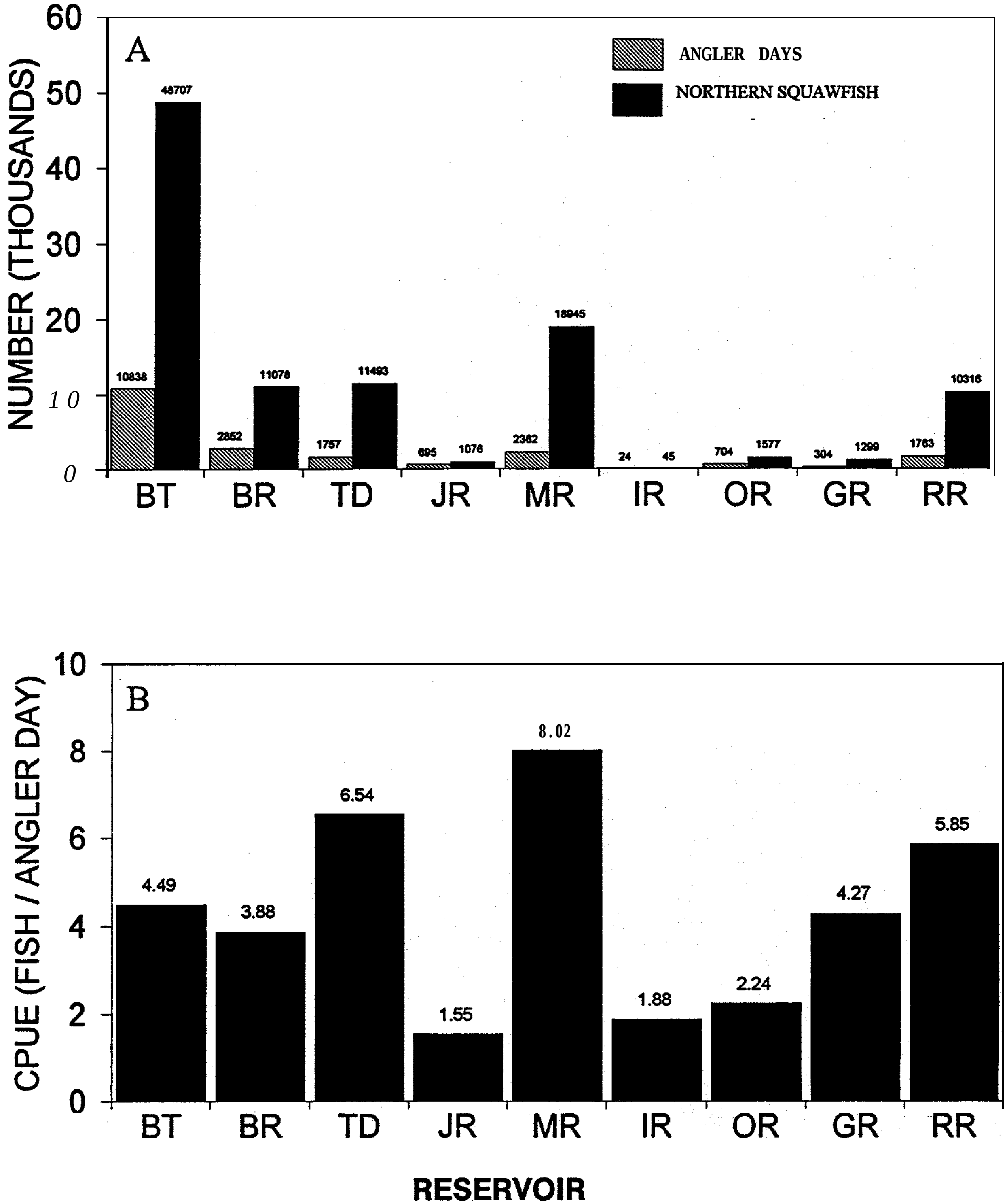


Figure 3. Sport-reward fishery data by reservoir for 1993. A - Effort (angler days) and northern squawfish catch by reservoir for 1993. B - CPUE (fish / angler day) by reservoir for 1993. BT - Bonneville Tailrace, BR - Bonneville Res., DR - The Dalles Res., JR - John Day Res., MR - McNary Res., IR - Ice Harbor Res., OR - Lower Monumental Res., GR - Little Goose Res., RR - Lower Granite Res.

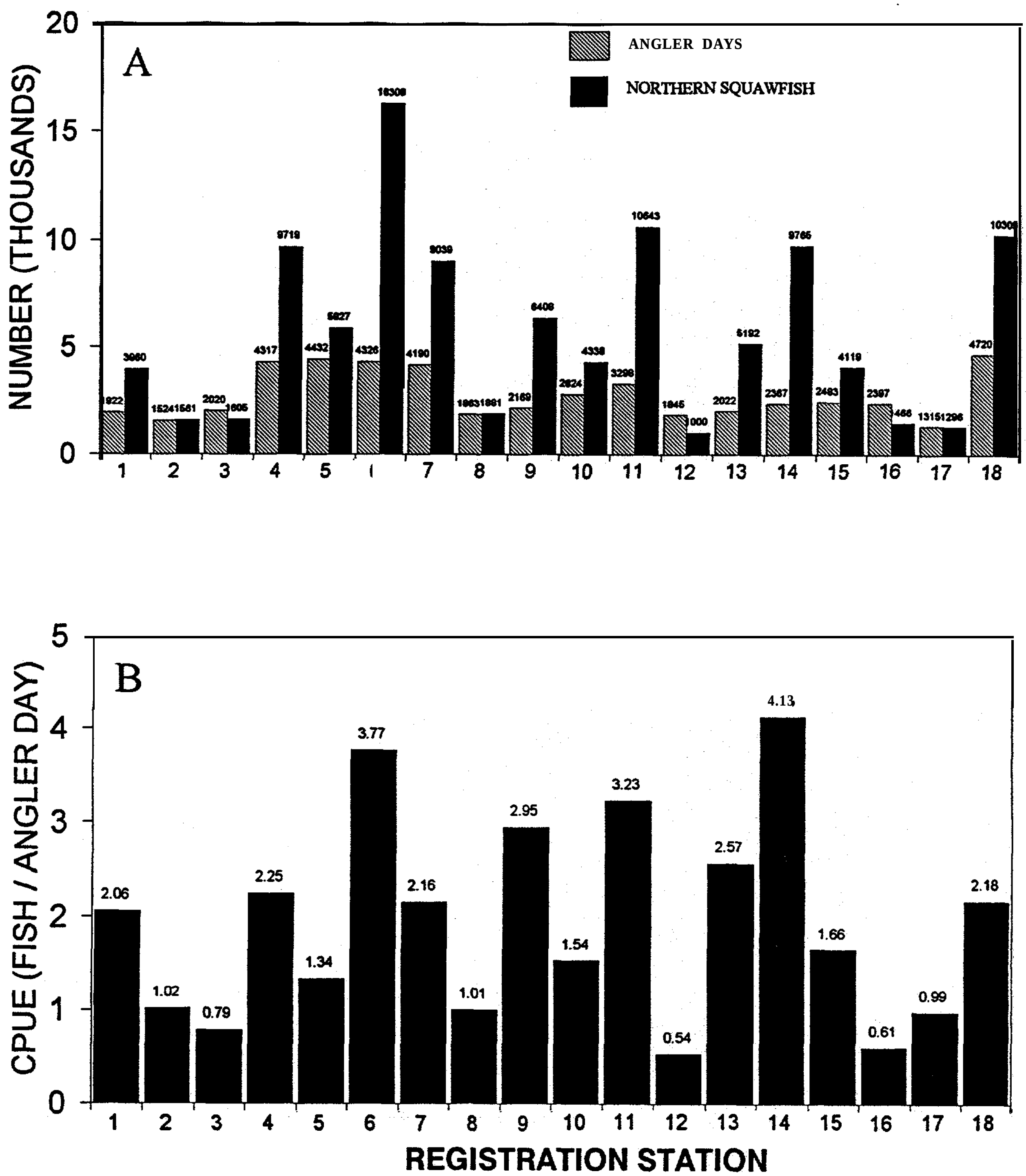


Figure 4. Sport-reward fishery data by registration station for 1993. A - Effort (angler days) and northern squawfish catch by registration station for 1993. B - CPUE (fish / angler day) by registration station for 1993. 1 - Cathlamet, 2 - Rainier, 3 - Kalama, 4 - Gleason, 5 - Camas, 6 - The Fishery, 7 - Hamilton, 8 - Cascade Locks, 9 - Bingen, 10 - The Dalles, 11 - LePage, 12 - Umatilla, 13 - Columbia Park, 14 - Vernita, 15 - Hood Park, 16 - Lyons Ferry, 17 - Boyer Park, 18 - Greenbelt.

Table 1. Comparison of registration stations during the 1991 (May 27-September 30), 1992 (May 18-September 30), and 1993 (May 3-September 12) seasons for northern squawfish harvest greater than 11 inches.

Station	1991	1992	1993
Hamilton Island	18219	17048	9126
The Fishery	40674	23851	16308
Cascade Locks	9143	6779	1881
Bingen Marina	12711	12513	6408
Dalles Boat Basin	3828[1]	6806	4338
LePage Park	32141	16926	10643
Columbia Point Park	1104[1]	11148	5192
Hood Park	3676[1]	9199	4119
Lyons Ferry	4211’	3131	1466
Greenbelt Boat Ramp	17466	21333	10309
Kalama Marina	--	6799	1605
Gleason Boat Ramp	--	15494	9719
Boyer Park	--	5875	1296
Cathlamet Marina	--	--	3960
Rainier Boat Ramp	--	--	1561
Camas/Washougal Boat Ramp	--		5920
Umatilla Boat Ramp	--	--	1000
Vemita Rest Area	--	--	9765
Maryhill State Park	1001[1]	5074	
Plymouth Boat Ramp	5556	2414	--
Windust Park	919[1]	--	--
Central Ferry State Park	7845	--	--
Chief Timothy State Park	1048	--	--
Willow Grove Park	--	5676	--
Marine Park (Portco)	--	8637	--
Ringold	--	5139	--
Bayport Marina	--	1606	--

[1] Stations did not open until July 15, 1991.
-- Not in operation.

A total of 75,219 northern squawfish were sampled for fork length in 1993. The mean length for all reservoirs combined was 326.6 mm (Figure 5). Mean lengths ranged from 309 mm in Bonneville Reservoir to 362.1 mm in The Dalles Reservoir (Figures 6-8). The range of fork lengths with the highest frequency that contained approximately 50% of the northern squawfish catch was 250-325 mm (53% of catch) for the Bonneville tailrace, 250-300 mm (63% of catch) for Bonneville Reservoir, 326425 mm (49% of catch) for The Dalles Reservoir, 326425 mm (39% of catch) for John Day Reservoir, 276-375 mm (46% of catch) for McNary Reservoir, 276-350 mm (54% of catch) for Ice Harbor Reservoir, 276-325 mm (66% of catch) for Lower Monumental Reservoir, 300-350 mm (69% of catch) for Little Goose Reservoir, and 300-400 mm (44% of catch) for Lower Granite Reservoir (Figures 6-8).

The northern squawfish catch for 1991, 1992 and 1993 peaked prior to July 15 in all years (Figure 9). The 1992 catch (186,904) was 79% greater than the 1993 catch (104,616) and 17% greater than the 1991 catch (159,162). The catch from each of the first -five weeks in 1992 was approximately 20,000 northern squawfish, which represented the major difference between the 1991-1992 catch and the 1993-1992 catch (Figure 9).

Effort (88,495 angler days) in 1992 was 154% greater than the 1993 effort (34,879 angler days) and 31% greater than the 1991 effort (67,384 angler days). Effort in 1992 was approximately three times greater than either 1991 or 1993 in the first five weeks of the fishery, which represented the major difference between the 1991-1992 effort and the 1993-1992 effort (Figure 9).

The mean CPUE for 1991 (2.37) was found to be significantly lower ($P<0.0001$) than the mean CPUE in 1992 (2.74) and the mean CPUE for 1993 (2.46) was found to be significantly lower ($P<0.0001$) than the mean CPUE for 1992 (2.74). The mean CPUE for 1991 (2.37) was not found to be significantly different ($P<0.0905$) than 1993 (2.46). CPUE peaked prior to July 15 in all three years (Figure 9).

A total of 68,797 fork lengths of northern squawfish greater than or equal to 250 mm were taken during the 1993 season, 119,437 during the 1992 season, and 59,650 during the 1991 season. The mean fork length for all reservoirs combined was 327 mm in 1993, 344 mm in 1992, and 349 mm in 1991. A statistically significant decrease in mean fork length was found between 1991-1992 ($P<0.0001$), 1992-1993 ($P<0.0001$) and 1991-1993 ($P<0.0001$).

4

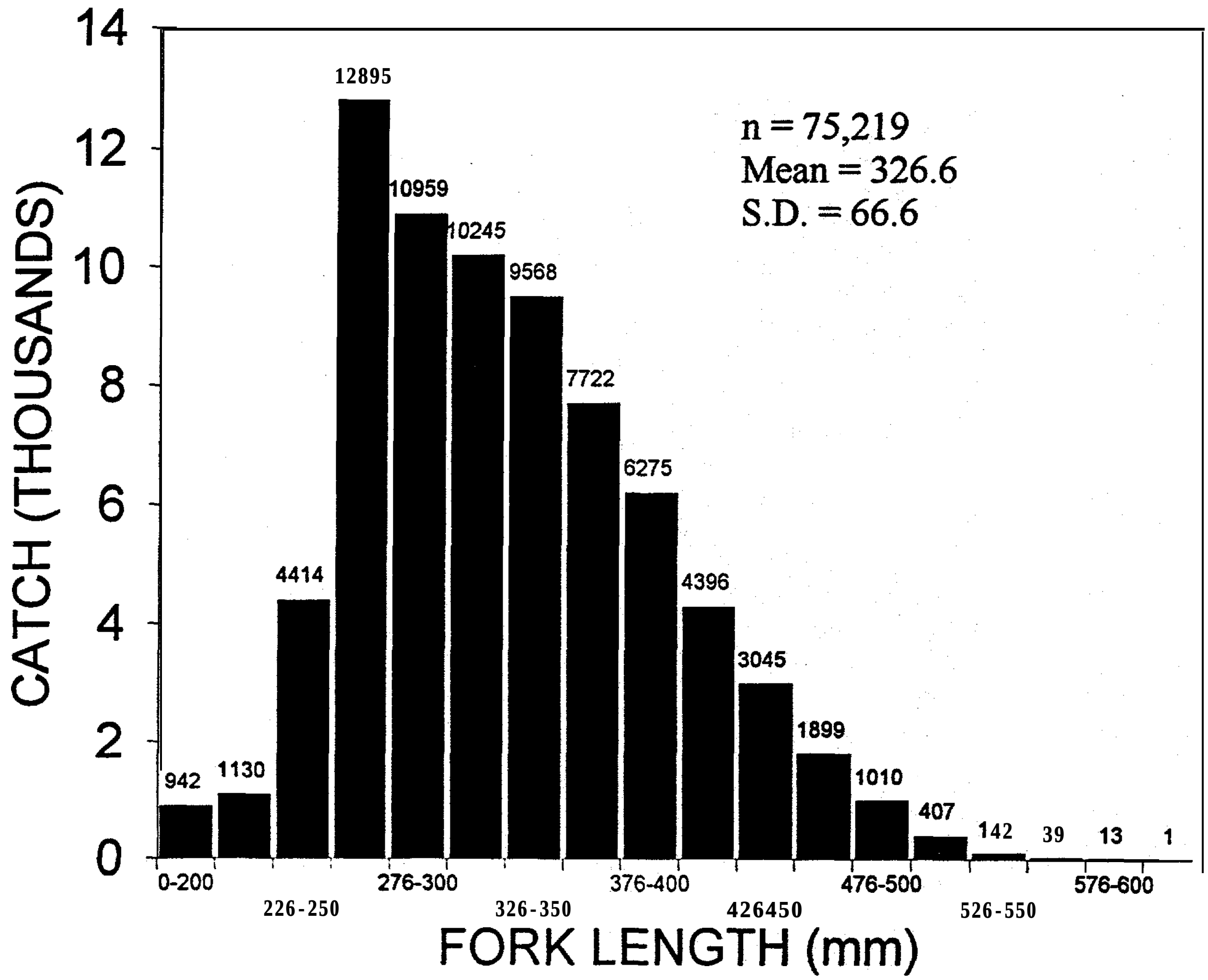


Figure 5. Overall length frequency distribution of northern squawfish sampled for fork length in the sport-reward fishery for 1993.

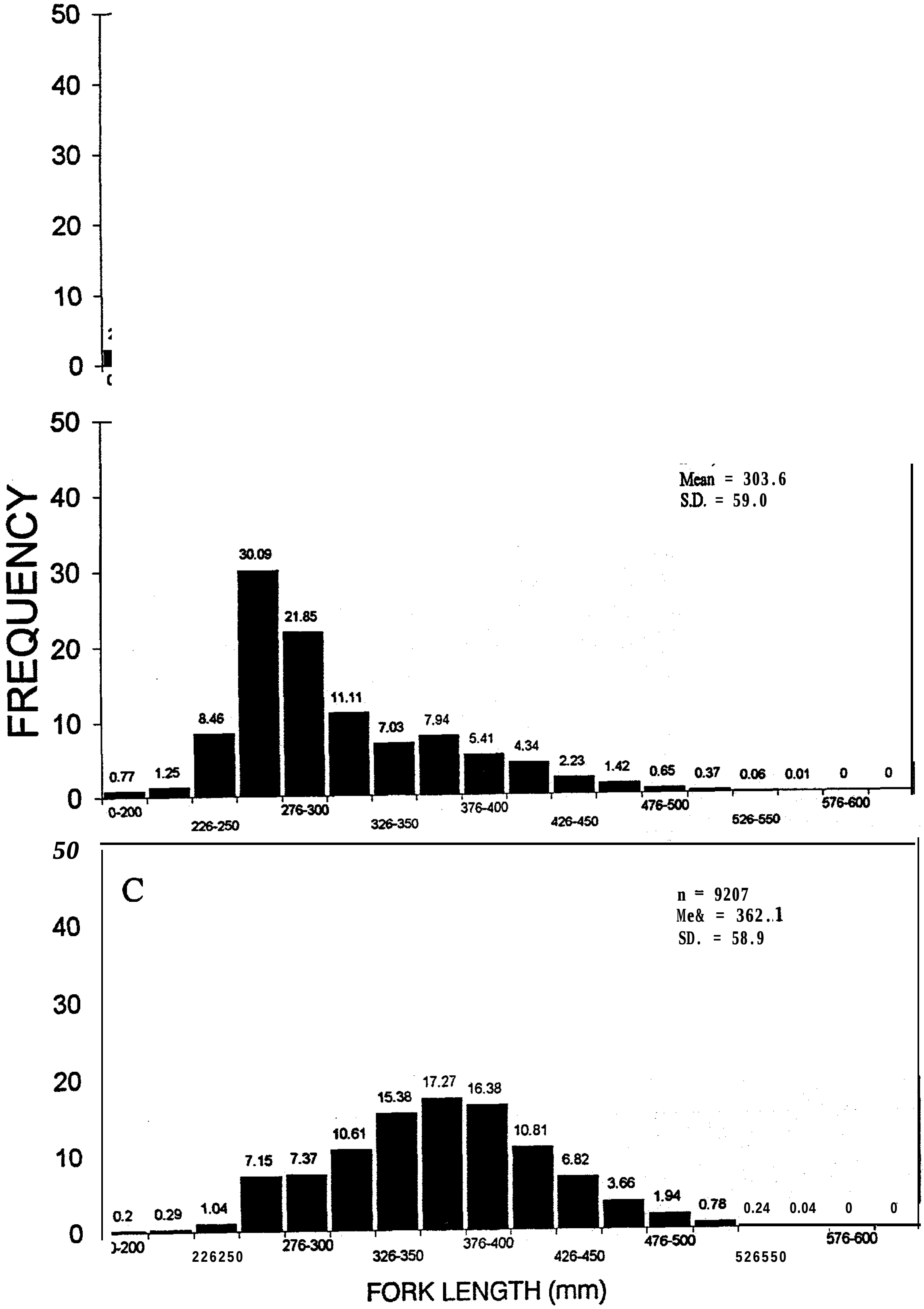


Figure 6. The percent of northern squawfish sampled in 25 mm length intervals by reservoir for 1993. A - Bonneville Tailrace. B - Bonneville Reservoir. C - The Dalles Reservoir.

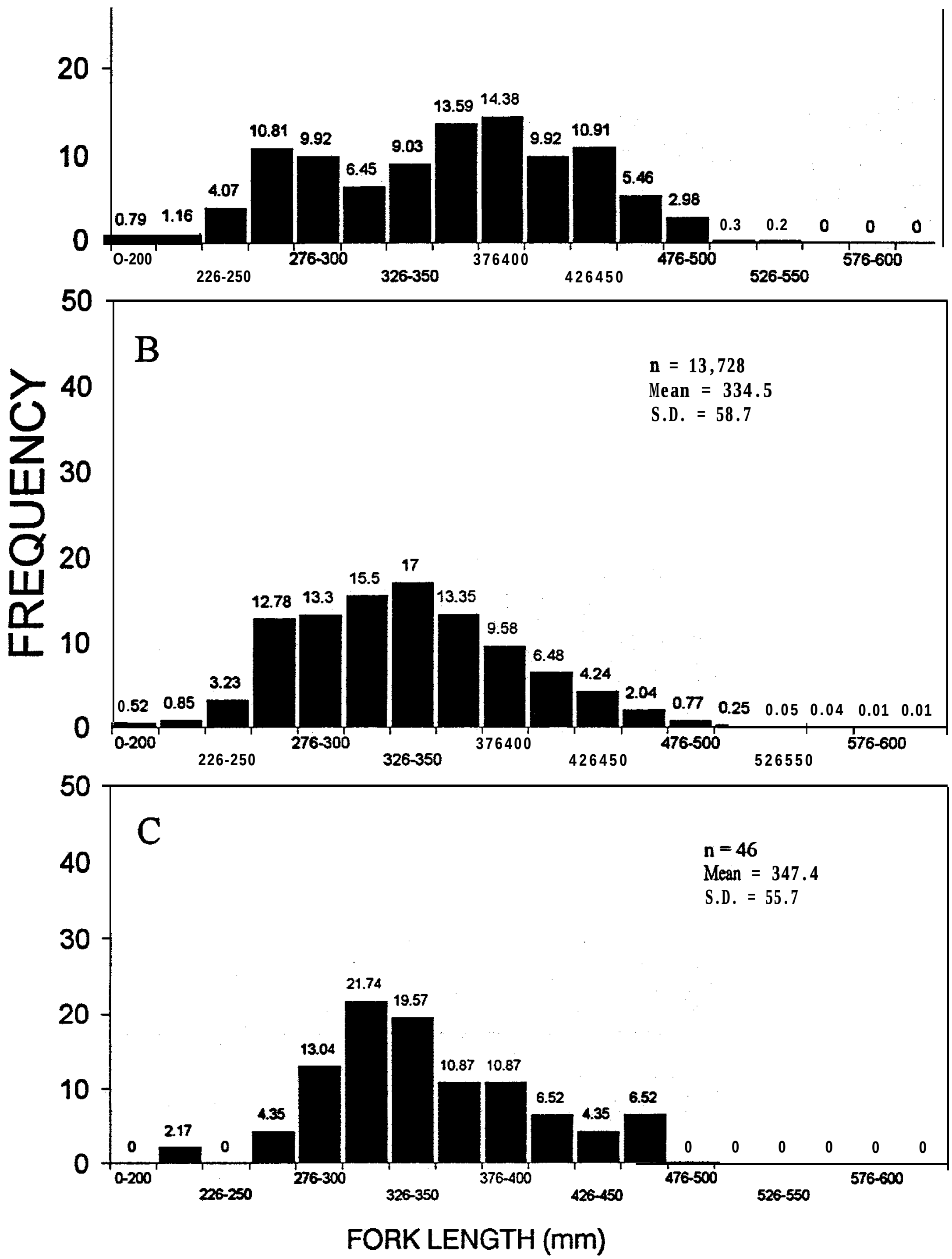


Figure 7. The percent of northern squawfish sampled in 25 mm length intervals by reservoir for 1993. A - John Day Reservoir. B - McNary Reservoir. C - Ice Harbor Reservoir.

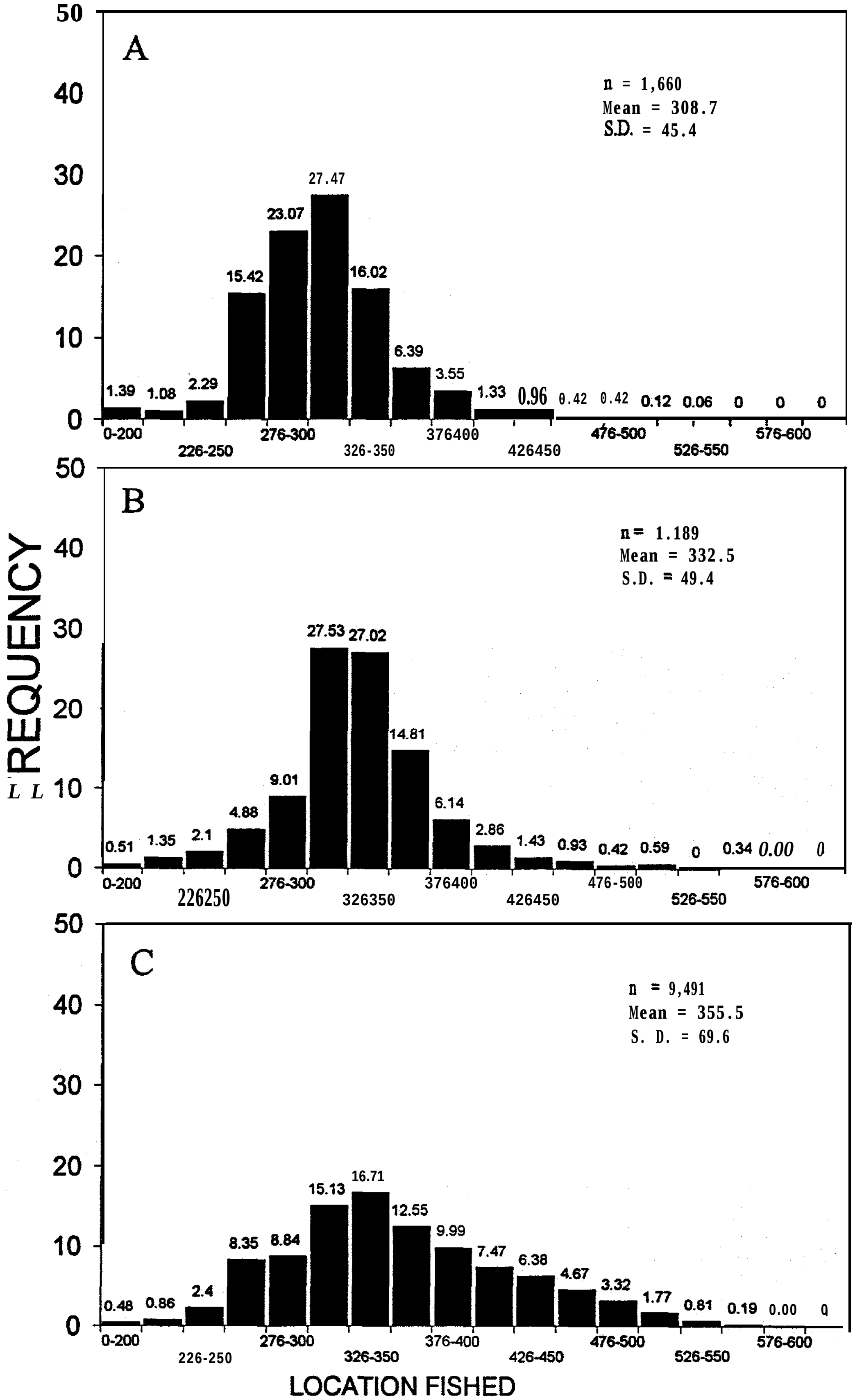


Figure 8. The percent of northern squawfish sampled in 25 mm length intervals by reservoir for 1993. A - Lower Mounumental Reservoir. B - Little Goose Reservoir. C - Lower Granite Reservoir.

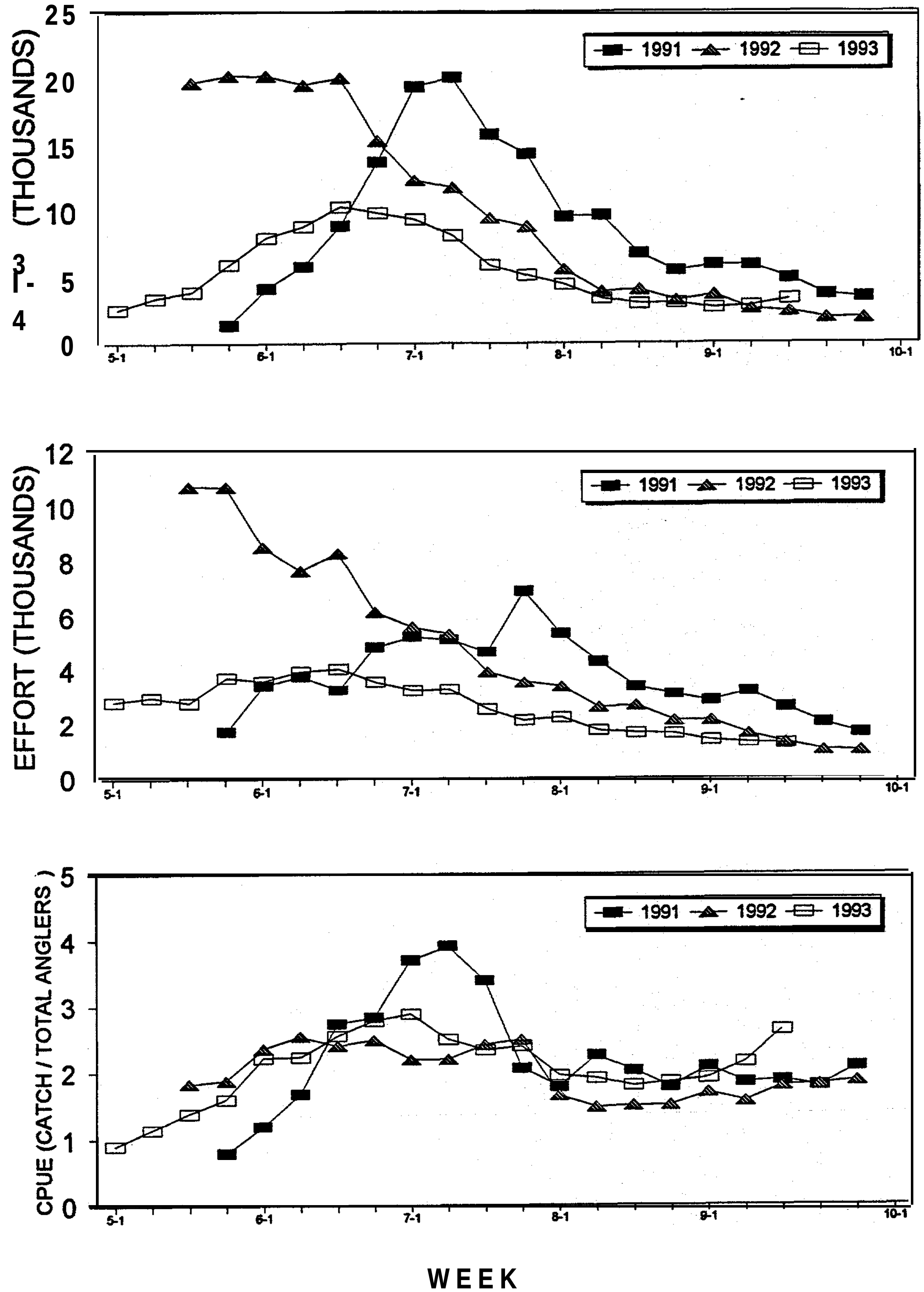


Figure 9. Comparison of the sport-reward fishery catch data by week for 1991, 1992, and 1993. A - Catch by week. B - Effort (angler days) by week. C - CPUE (fish / angler day) by week.

We observed that five out of nine reservoirs showed a statistically significant decrease in mean fork length from 1991 to 1993 (Table *2).* Little Goose Reservoir, John Day Reservoir and Ice Harbor Reservoir showed no significant change in mean fork lengths from 1991 to 1993. The model was not significant **($P < 0.7$)** for the mean fork length comparison in John Day Reservoir even though the lsmeans test **($P < 0.0275$)** did show a significance decrease in mean fork length between 1991 and 1993. The mean fork length in Ice Harbor Reservoir did decrease from 361 mm to 350 mm, but the 1993 sample size of 45 fish was too small to give an accurate estimate. No registration station operated in Ice Harbor Reservoir for the 1993 season. Lower Granite Reservoir showed a statistically significant increase in mean fork length from 1991 to 1993.

Game, Food, and Unclassified Fish Species Catch Data

A total of 2,100 fish other than northern squawfish were turned into the registration stations by returning anglers (Table 3). We observed a harvest of 702 **peamouth** chub ***(Mylocheilus caurinus)*** which was the most observed of the game fish species. There were 493 smallmouth bass ***(Micropterus dolomieui)*** harvested, followed by 202 channel catfish ***(Ictalurus punctatus,)*** and 121 walleye ***(Stizostedion vitreum).*** We also observed harvest of a suspected hybrid between the northern squawfish and chislemouth chub ***(316*** fish). These fish were termed "Columbia River chub" for reporting purposes.

Harvest of fish species other than northern squawfish were examined in regards to an angler's target species. **Peamouth** chub were returned to the check stations more frequently than any other fish species, other than northern squawfish. All **peamouth** chub were caught incidental to the program. Smallmouth bass, channel catfish and walleye are popular game fish. Seventy-one percent of the 493 smallmouth bass harvested were taken by anglers targeting smallmouth bass. Of the 202 channel catfish harvested, 66% were targeted; 76% of the 121 walleye harvested were targeted.

The 2,100 fish, other than northern **squawfish,** harvested by registered anglers in 1993 was 249 fish less than the 1992 season (2,349) and 258 less than the 1991 season (2,358; Table 4). Warmwater species accounted for the majority of the harvest.

Table 2. Mean fork length comparison of 1991, 1992, and 1993 (Pr > [t] estimates the probability of the mean fork length being significantly different from 1991 to 1993).

Reservoir	Year	n	mean	Pr > [t]
Bonneville Tailrace	1991	9698	341	
	1992	41842	334	0.0001
	1993	28047	321	
Bonneville	1991	7550	349	
	1992	8457	353	0.0001
	1993	6481	310	
The Dalles	1991	8563	371	
	1992	17043	364	0.0001
	1993	9101	364	
John Day	1991	2821	371	
	1992	2508	370	0.0275
	1993	956	365	
McNary	1991	4701	356	
	1992	17024	350	0.0001
	1993	13197	339	
Ice Harbor	1991	890	360	
	1992	4565	362	0.2419
	1993	45	350	
Lower Monumental	1991	3642	319	
	1992	2897	309	0.0001
	1993	1586	313	
Little Goose	1991	1902	337	
	1992	4748	330	0.8650
	1993	1147	337	
Lower Granite	1991	19122	348	
	1992	19464	350	0.0001
	1993	9150	360	
Combined Totals	1991	59650	350	
	1992	119437	346	0.0001
	1993	68797	335	

Table 3. Total of all species of fish excluding northern squawfish turned in to the registration stations during 1993.

Common Name	Scientific Name	Code	Total
American shad	*Alosa sapidissima*	AMS	28
Bridgelip sucker	*Catostomus columbianus*	BRS	20
Brown bullhead	*Ictalurus nebulosus*	BBH	7
Bullhead (general)	*Ameiurus spp.*	BH	10
Carp	*Cyprinus carpio*	CP	7
Channel catfish	*Ictalurus punctatus*	CC	202
Chinook Salmon	*Oncorhynchus tshawytscha*	CK	5
Chiselmouth	*Acrocheilus alutaceus*	CMO	87
Coho Salmon	*Oncorhynchus kisutch*	CO	1
Columbia River chub[1]		CRC	316
Crappie (general)	*Pomoxis spp.*	C	4
Largemouth bass	*Micropterus salmoides*	LMB	2
Largescale sucker	*Catostomus microps*	LRS	7
Peamouth	*Mylocheilus caurinus*	PMO	702
Pumpkinseed	*Lepomis gibbosus*	PS	1
Rainbow trout(res.)	*Oncorhynchus mykiss*	RB	7
Rainbow trout(unk.)	*Oncorhynchus mykiss*	RU	2
Sandroller	*Percopsis transmontana*	SAN	1
Sculpin (general)	*Cottus spp.*	COT	1
Sculpin, Torrent	*Cottus rhotheus*	TRS	1
Searun cutthroat	*Oncorhynchus clarki*	SCT	2
Smallmouth bass	*Micropterus dolomieui*	SMB	493
Starry flounder	*Platichthys stellatus*	SF	2
Steelhead (summer)	*Oncorhynchus mykiss*	SS	20
Steelhead (unknown)	*Oncorhynchus mykiss*	SH	3
Sucker (general)	*Catostomus spp.*	SK	3
Trout (unknown)	*Oncorhynchus spp.*	TR	5
Walleye	*Stizostedion vitreum*	WAL	121
White crappie	*Pomoxsis annularis*	WC	1
Whitefish, mtn.	*Prosopium williamsoni*	WF	3
White sturgeon	*Acipenser transmontanus*	WS	11
Yellow bullhead	*Ictalurus natalis*	YBH	9
Yellow perch	*Perca flavescens*	YP	16
Total			2100

[1] Probable northern squawfish/chiselmouth hybrid; named "Columbia River chub" for reporting purposes.

Table 4. Yearly totals of all species of fish excluding northern squawfish turned in to the registration stations.

Common Name	Code	1991	1992	1993
American shad	AMS	6	54	28
Black crappie	BC	44	3	0
Bluegill	BG	3	3	0
Bridgelip sucker	BRS	9	8	20
Brown bullhead	BBH	8	18	7
Bullhead (general)	BH	4	4	10
Bull trout	BLC	‘1	0	0
Carp	CP	6	19	7
Channel catfish	c c	453	141	202
Chinook Salmon	CK	0	7	5
Chiselmouth	CMO	106	139	87
Chum salmon	CH	0	1	0
Coho Salmon	c o	0	0	1
Columbia River chub’	CRC	192	125	316
Crappie (general)	C	23	3	4
Cutthroat trout	CT	5	0	0
Largemouth bass	LMB	3	9	2
Longnose sucker	LNS	0	1	0
Large-scale sucker	LRS	4	11	7
Peamouth	PMO	368	588	702
Pumpkinseed	PS	1	2	1
Rainbow trout (res.)	RB	25	9	7
Rainbow trout (unk.)	RB	20	113	2
Redside shiner	RS	1	2	0
Sandroller	SAN	0	0	1
Sculpin (general)	COT	2	10	1
Sculpin, Prickly	PRS	0	1	0
Sculpin, Torrent	TRS	0	0	1
Searun cutthroat	SCT	0	1	2
Smallmouth bass	SMB	770	693	493
Sockeye salmon	s o	0	2	0
Starry flounder	SF	2	9	2
Steelhead (summer)	s s	10	40	20
Steelhead (unknown)	SH	18	9	3
Steelhead (winter)	SW	1	13	0

Table 4. Continued.

Common Name	Code	1991	1992	- 1993
Sucker (general)	SK	11	21	3
Tench	TNC	1	0	0
Trout (unknown)	TR	0	0	5
Walleye	WAL	184	231	121
Warmouth	WM	2	0	0
White crappie	WC	20	0	1
Whitefish, mountain	WF	3	5	3
White sturgeon	w s	9	17	11
Yellow bullhead	YBH	0	0	9
Yellow perch	YP	43	36	16
Totals		2358	2349	2100

[1] Probable **NSF/CMO** hybrid; named "Columbia River chub" for this report.

DISCUSSION

Northern Squawfish Harvest Data

Harvest varied by week in 1991, 1992 and 1993, but the peak harvest occurred prior to July 15 in all years. Northern squawfish aggregate in spawning areas prior to spawning (Patten and Rodman 1969). Anglers have informally reported to technicians that northern squawfish feed more aggressively prior to spawning in the Columbia and Snake rivers from mid-May until mid-July, which would make them more vulnerable to catch and explain why the harvest peaks prior to July 15. Water conditions such as temperature can also affect the spawning time of northern squawfish (Patten and Rodman 1969). Variation in spawning time among years could partially explain the variation in the timing of peak catch among years (Figure 9). Anglers participating in the 1993 program often complained to technicians that the high and turbid water conditions, along with the frequent rain, were decreasing their participation in the program. Angler effort in 1993 was lower than effort in 1991 and 1992, which was the major factor contributing to the low catch in 1993. The catch and catch-per-unit-effort were higher in 1992 than 1991 or 1993 (Figure 9) because 1992 was the only year that effort was high in the beginning of the field season prior to spawning. High angler effort prior to July 15 will be necessary to produce high catches in future sport-reward program field seasons.

The decrease in the 1993 effort was not due to reservoir specific factors since effort (returning angler days) by reservoir in 1993 decreased in all nine reservoirs when compared to 1992 data. When the 1993 data was compared to 1991, McNary Reservoir showed the only increase in effort (613 returning angler days) while the other eight reservoirs showed reduced effort.

In evaluating the number of registration stations and their placement for the 1994 sport-reward fishery, we used three variables: (1) overall harvest of northern squawfish by registration station, (2) the reservoir specific predation index values, and (3) the current annual exploitation of northern squawfish in that reservoir. Boyer Park, in Little Goose Reservoir, Lyons Ferry Marina in Lower Monumental Reservoir, Cascade Locks in Bonneville Reservoir, and Rainier Boat Ramp in Bonneville Tailrace were excluded from the 1994 fishery since the closure of these stations would have the least impact on the overall goal to achieve a 10-20% exploitation rate systemwide and still allow for the required budget reductions. By request from the Corps of Engineers, Lepage Park (John Day Reservoir) will be relocated to Giles French Boat Ramp (The Dalles Reservoir). We do have some concerns that closing stations will eliminate or greatly reduce harvest in Lower Monumental and Little Goose reservoirs, as was the case in Ice Harbor Reservoir during the 1993 fishery (Windust Park was eliminated).

Registration station operations should be reduced to one shift a day from 1 p.m. to 9 p.m. seven days per week to maximize participation while reducing overall costs of the program. Data from past years indicated that 70% of the anglers participating in the program would not have to change the normal time they turn in fish under the proposed change in hours of operation. Self registration will be available during unstaffed hours and the 30% of anglers that will have to adjust their schedules will hopefully continue participation in the program.

It is unclear if the reduction in mean fork length found in northern squawfish returned to the sport-reward fishery represents a change in the mean fork length of the respective populations of northern squawfish or if those changes could be attributed to increased exploitation. Other factors such as changes in northern squawfish year-class strength, sport-reward fishery sample not being representative of the true northern squawfish population, mixing of northern squawfish between reservoirs, or illegally caught northern squawfish could cause changes in mean fork length. A significant decrease in mean fork length in five out of nine reservoirs and a significant decrease in overall mean fork length may indicate that exploitation lowered the average size of northern squawfish and thereby reduced predation on juvenile salmonids (Table 2). Continued monitoring of the sport-reward fisheries mean fork length along with ODFW's analysis of year-class strength estimates should confirm if the observed fork length decreases were representative of the population.

The overall exploitation rate systemwide for the three harvest techniques (sport-reward, dam-angling, and trap net) was 8.54% (Zimmerman et al., unpublished data). The sport-reward fishery was shown to be the most successful northern squawfish harvest technique since the program was responsible for 79% of total, systemwide exploitation. The program goal of 10-20% exploitation was not reached, but the current level of participation in the sport-reward program was achieved with no organized promotion. An organized promotional campaign, implemented at the beginning of the field season, could help to achieve the exploitation goals. Additional incentives to increase participation should be addressed in 1994 by incorporating an aggressive media campaign (on and off season), organized derbies, tournaments, and lottery type events.

The Washington Department of Fish and Wildlife in coordination with the Oregon Department of Fish and Wildlife have taken steps to codify rules and regulations for the sport-reward fishery. We will be reviewing the regulations to evaluate the effectiveness of current guidelines and apply adjustments to the 1994 sport-reward fishery where necessary.

Changing the time for the field season by itself does not sufficiently increase catch since the 1993 sport-reward fishery began and ended two weeks earlier (May 3-September 12) than the 1992 season (May 18-September 30) and the 1993 fishery began three weeks earlier and ended two weeks earlier than the 1991 season (May 27-September 30). The adjustment in field season timing will only be effective if increased angler participation can also be achieved, especially during the time prior to northern squawfish spawning.

Game, Food, and Unclassified Fish Species Catch Data

The 1993 phone survey estimates of the non-returning anglers' catch was higher for every species than the proportional estimate obtained from the number of fish observed at the registration stations. Technicians are required to observe the fish caught by returning anglers before recording them in the catch data. Anglers are in a hurry when they return to the registration stations and often do not wish to take the time to show all of their catch. The anglers' potential unwillingness to show their entire catch could account for the discrepancy between the telephone survey catch estimates and the registration station catch data. We feel the phone survey reflects a more accurate account of other fish species harvested. The harvest on other fish species is currently at low levels, but we need continued monitoring of this trend through angler exit interviews and the phone survey to aid in obtaining information on harvest of ESA listed species as well as non-listed species.

Recommendations For 1994 Sport-Reward Fishery Season

1. The timing of the fishery should be similar to last year's early May through mid-September schedule.

2. Field operations should be limited to one shift per day (e.g., 1 p.m. - 9 p.m.) seven days per week. Self registration should continue to be available during unstaffed hours.

3. Location and number of registration stations should be placed systemwide in areas that will contribute and maintain targeted systemwide exploitation rates to reduce salmonid losses due to predation while reducing the budget. Specifically, eliminate Boyer Park, Lyons Ferry Marina, Cascade Locks Marina, and Rainier Boat Ramp.

4. Relocate LePage Park registration station to Giles French Boat ramp.

5. Discontinue the use of the computerized data collection unit due to limited success and efforts to reduce budget.

6. Continue a streamlined phone survey to address the non-returning angler in relation to other fish species harvest and registration station personnel interactions.

7. Implement an aggressive public relations effort to increase awareness of the program and increase participation.

8. Coordinate with outside groups to conduct supplemental incentive programs to increase participation in the fishery.

REFERENCES

Burley, C.C., D.C. **Klaybor,** G.W. Short, and G.J. Hueckel. 1992. Evaluation of the northern squawfish sport-reward fishery in the Columbia and Snake rivers. Report E *in* C.F. Willis and A.A. Nigro, eds. Development of a System-wide Predator Control Program: **Stepwise** Implementation of a Predation Index, Predator Control Fisheries, and Evaluation Plan in the Columbia River Basin. 1991 Annual Report. Contract **DE-BI179-90BP07084,** Bonneville Power Administration, Portland, Oregon.

Dillman, D.A. 1978. Mail and telephone surveys. Wiley-Interscience Publications.

Hanna, S., B. Anteneh, J. **Pampush,** M. Morrissey, D. Lin, and E. Foster. 1992. Economic, social, and legal feasibility of commercial, sport and bounty fisheries on northern squawfish. Oregon State University, Corvallis.

Nigro, A.A., editor. 1990. Developing a predation index and evaluating ways to reduce **salmonid** losses to predation in the Columbia River Basin. Oregon Department of Fish and Wildlife, 1990 Final Report. Contract **DE-AI79-88BP92122,** Bonneville Power Administration, Portland, Oregon.

NPPC (Northwest Power Planning Council). 1987. Columbia River Basin fish and wildlife program. Adopted November 15, 1982, amended October 10, 1984, and February 11, 1987. Northwest Power Planning Council, Portland, Oregon.

Patten, B.G., and D.T. **Rodman.** 1969. Reproductive behavior of northern squawfish, ***Ptychocheilus oregonesis.*** Transactions of the American Fisheries Society **98(** 1): **108-** 110.

Rieman, **B.E.,** and R.C. Beamesderfer. 1990. Dynamics of a northern squawfish population and the potential to reduce predation on juvenile salmonids in a Columbia River reservoir. North American Journal of Fisheries Management **10:228-241.**

Rieman, B.E., R.C. Beamesderfer, S. Vigg, and T.P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day reservoir. North American Journal of Fisheries Management 120:448- ***458.***

SAS Institute, Inc. 1988. SAS/STAT user's guide, release 6.03 edition. SAS Institute, Inc., Cary, North Carolina.

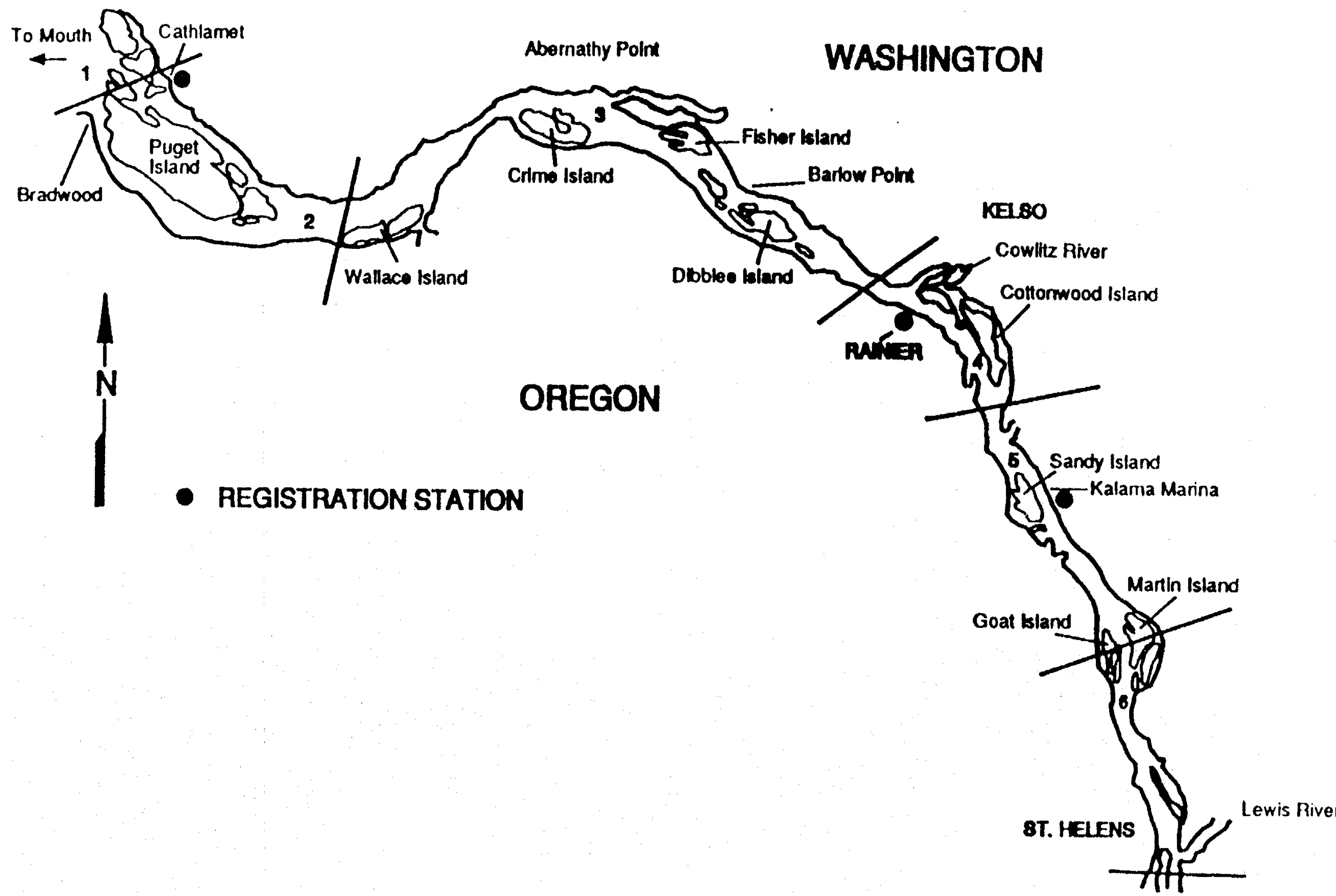
Scheaffer, R.A., W. Mendenhall, and L. Ott. 1990. Elementary survey sampling. Duxbury Press, Belmont, California.

Vigg, S., C.C. Burley, D.L. Ward, C. Mallette, S. Smith, and M. Zimmerman. 1990. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. Report A *in* A.A. Nigro, editor. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River basin. Oregon Department of Fish and Wildlife, Contract DE-BI79-90BP07084. Annual Report to Bonneville Power Administration, Portland, Oregon.

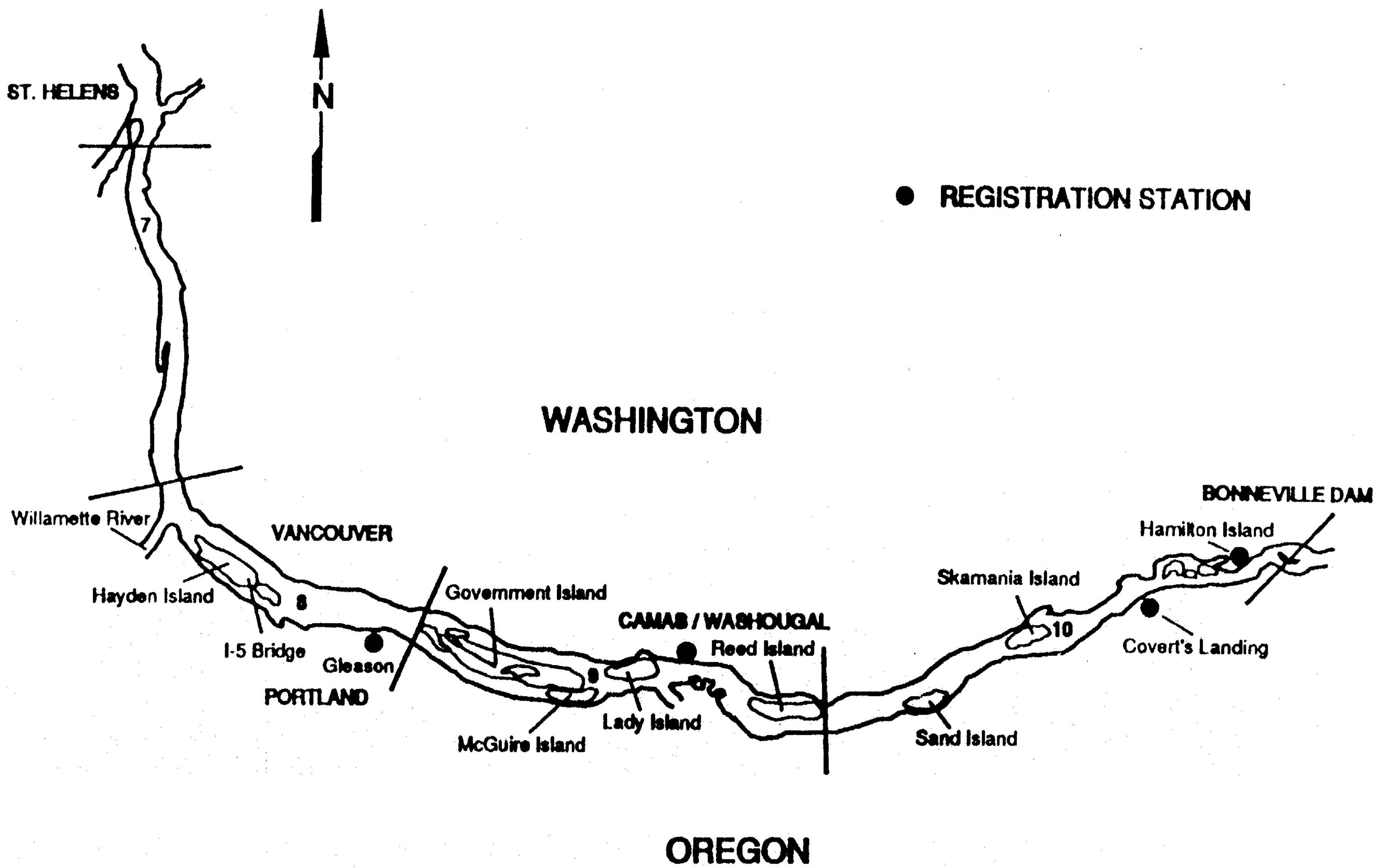
Zimmerman M., C.J. Knutsen, D.L. Ward, K. Anderson. Unpublished. Development of a system-wide predator control program: indexing and fisheries evaluation. Report G *in* A.A. Nigro, editor. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River basin. Oregon Department of Fish and Wildlife, **Contract DE-BI79-90BP07084.** Annual Report to Bonneville Power Administration, Portland, Oregon.

APPENDIX A

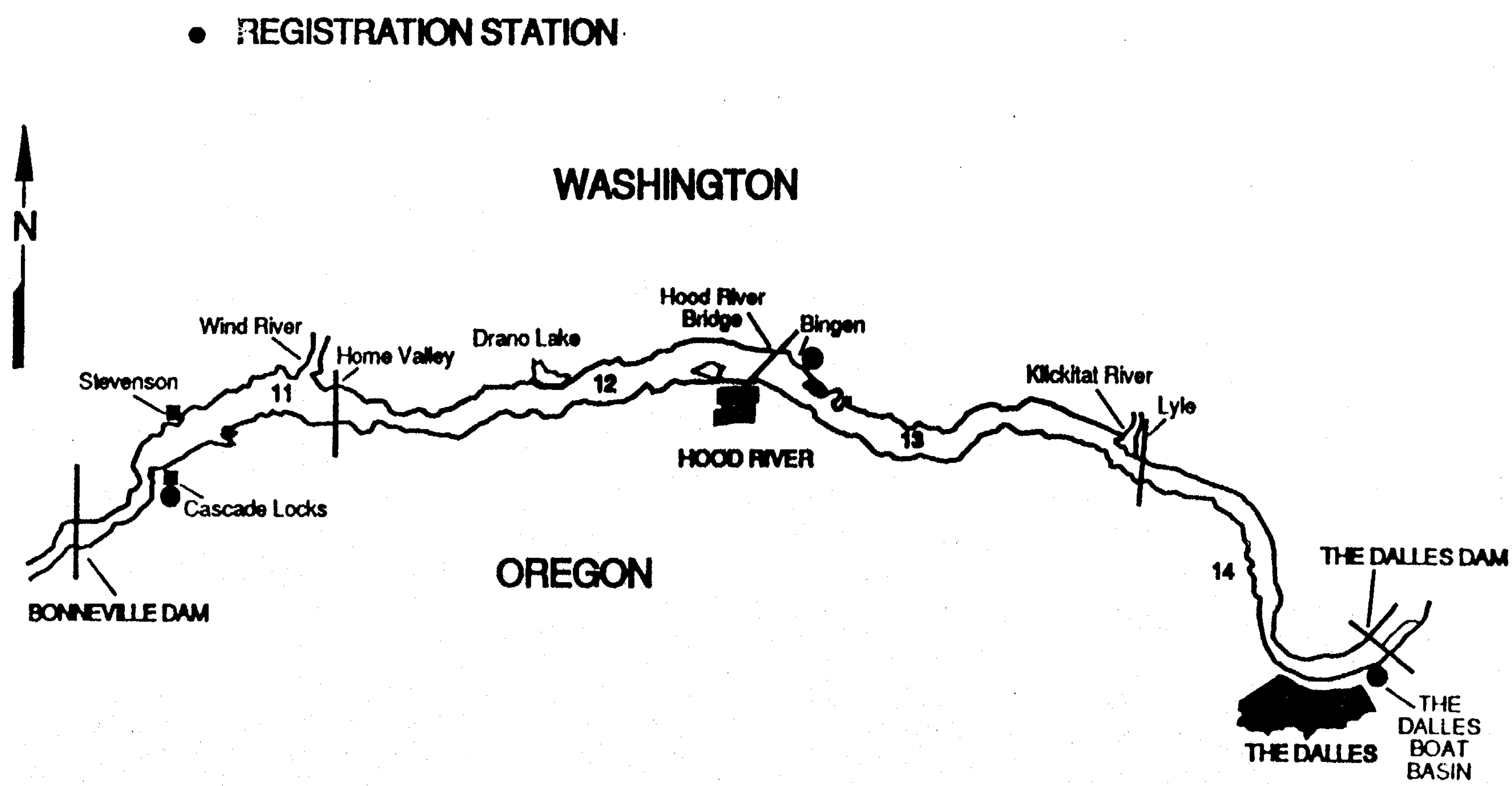
Maps Showing Fishing Locations and Codes



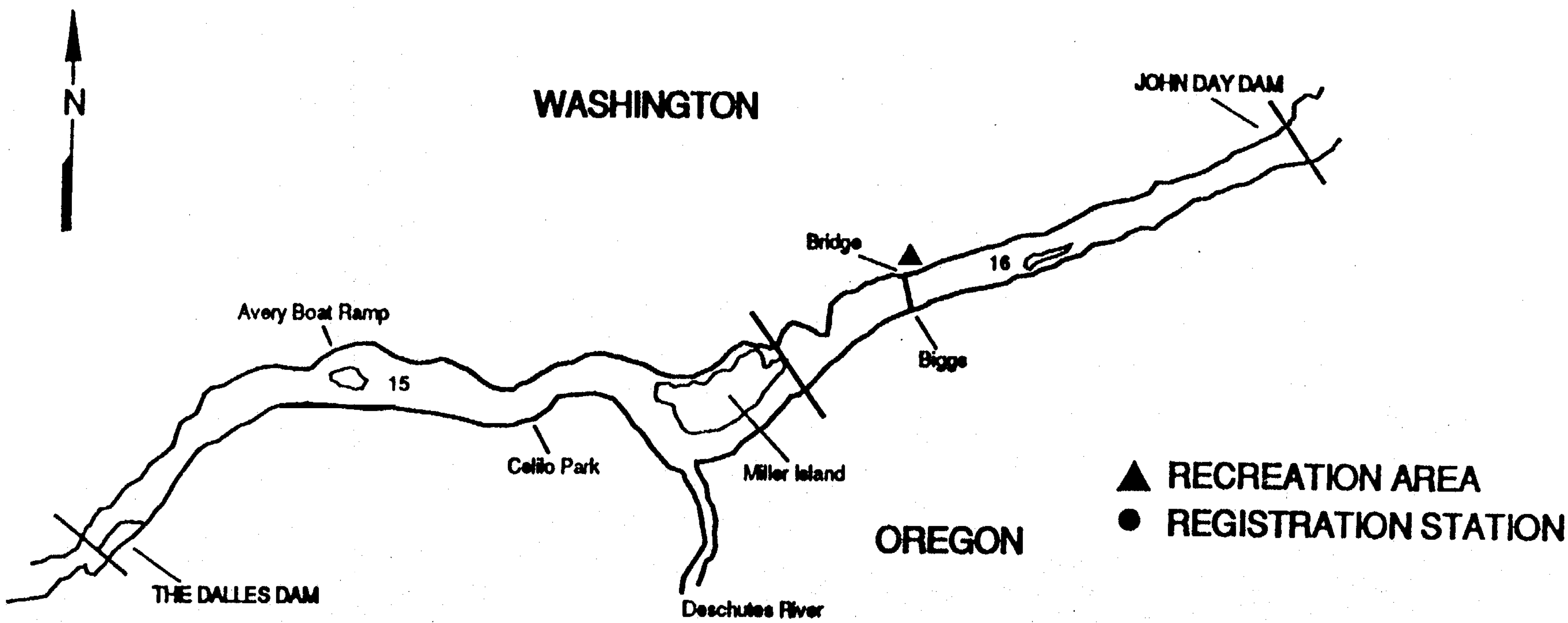
Appendix Figure A-1. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, mouth of Columbia River to Lewis River.



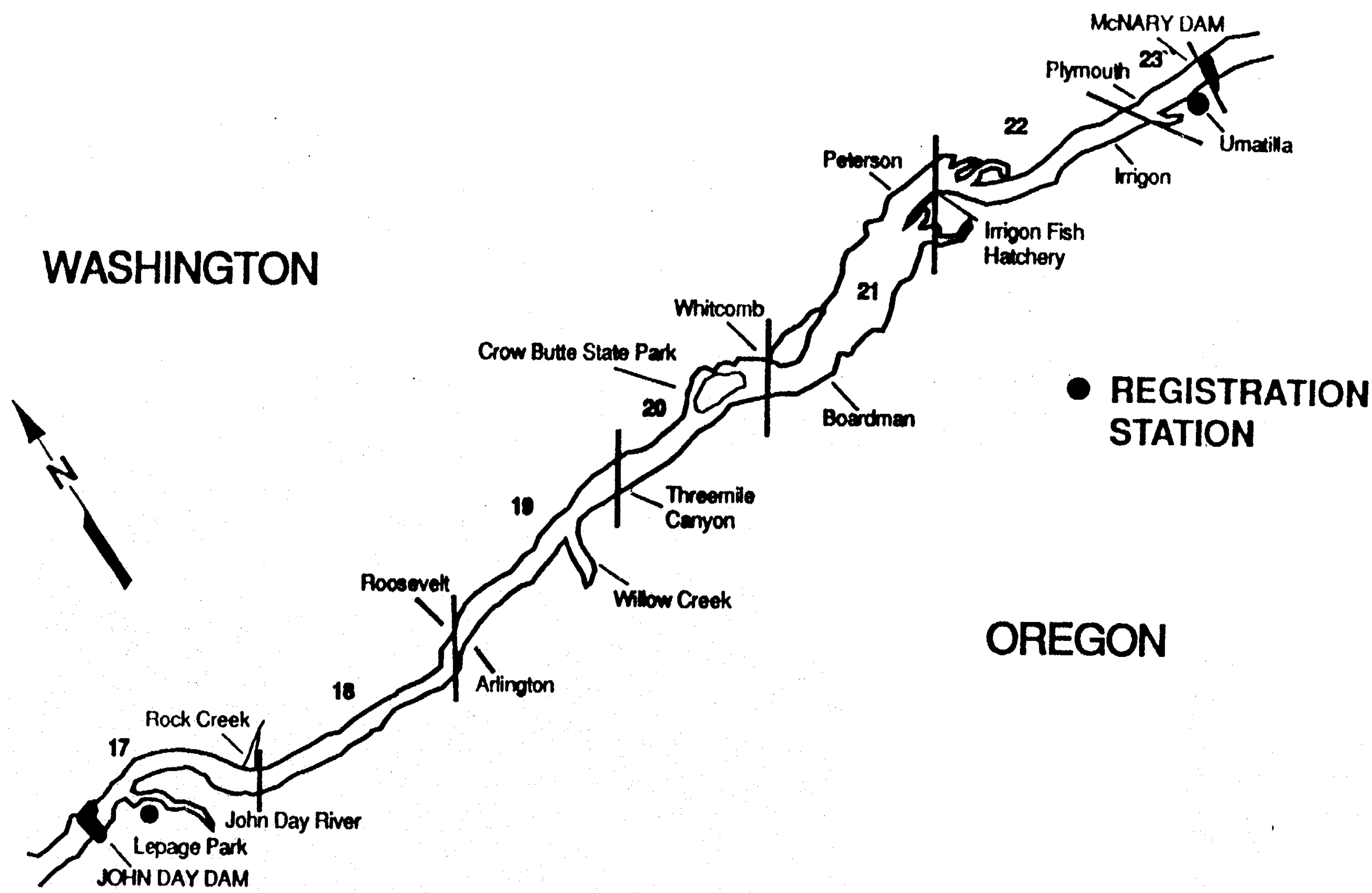
Appendix Figure A-2. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, Lewis River to Bonneville Dam.



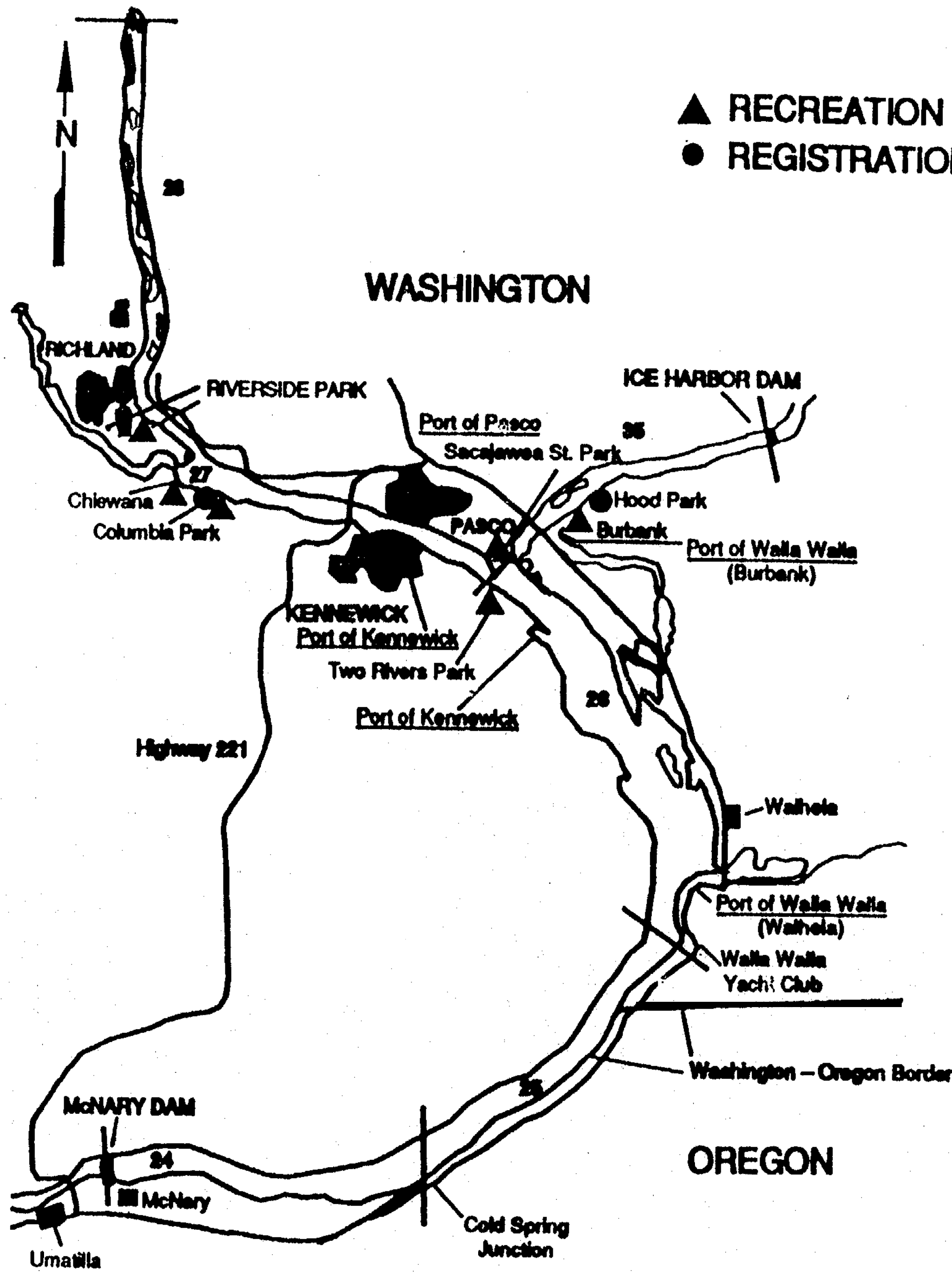
Appendix Figure A-3. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, Bonneville Dam to The Dalles Dam.



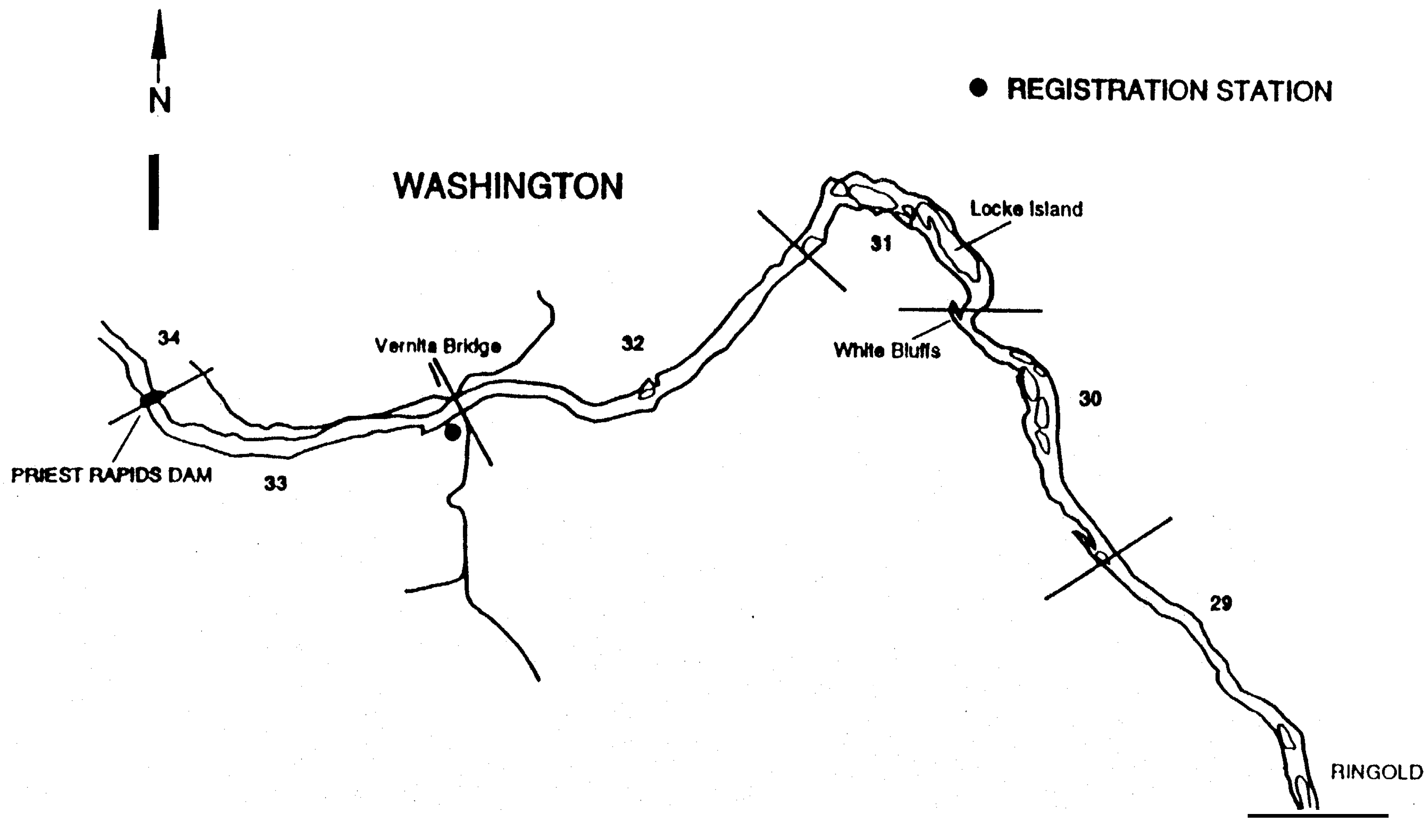
Appendix Figure A-4. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, The Dalles Dam to John Day Dam.



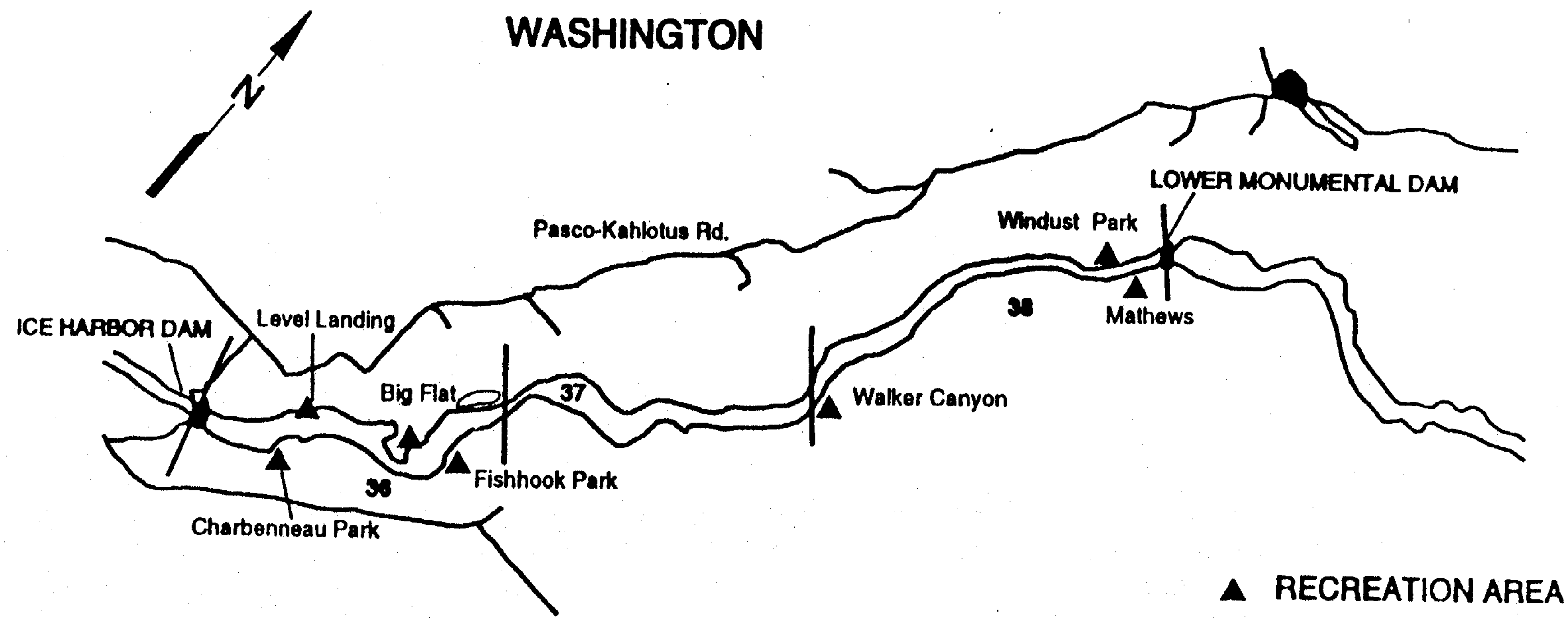
Appendix Figure A-5. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, John Day Dam to McNary Dam.



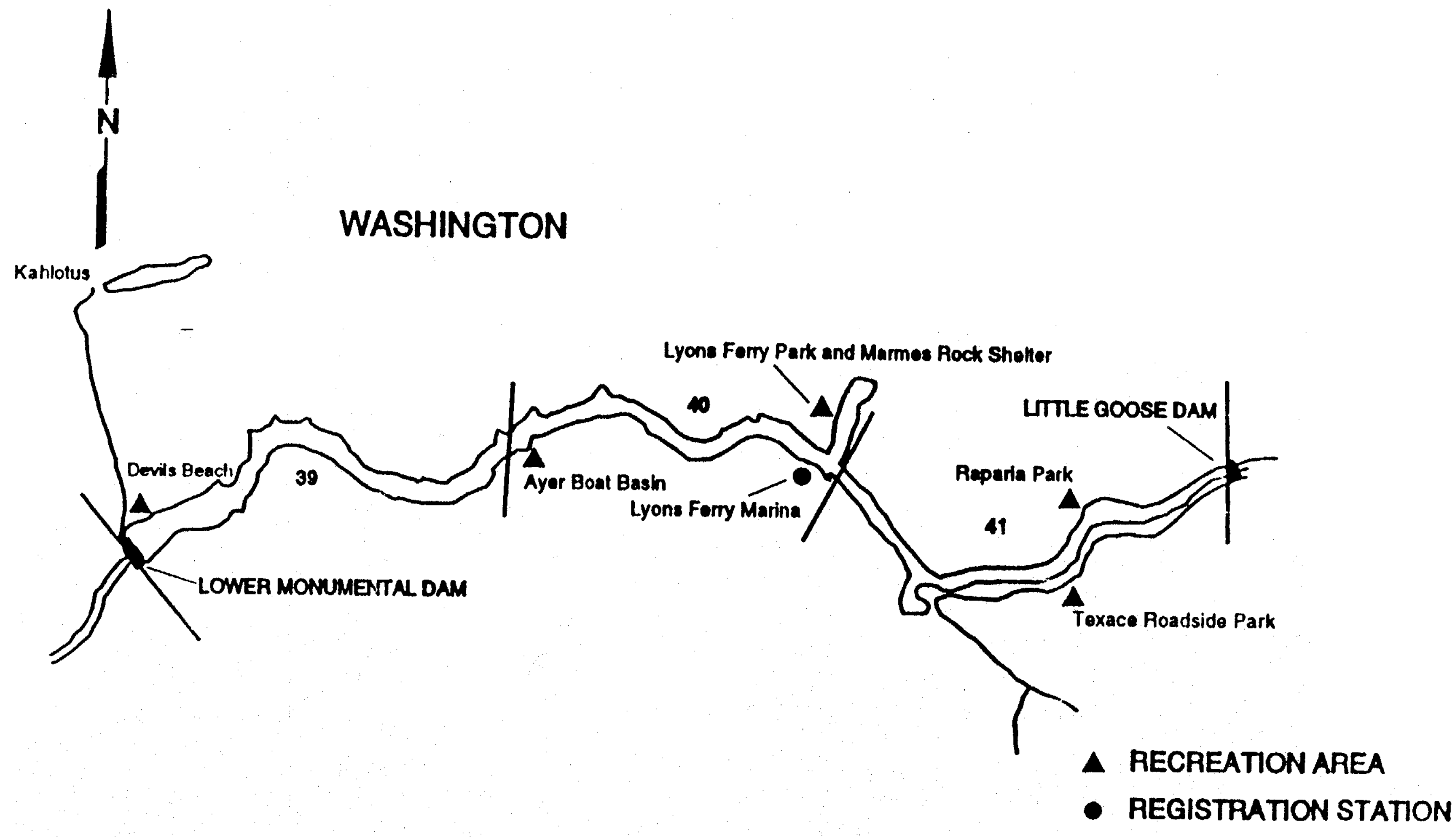
Appendix Figure A-6. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, McNary Dam to Ringold Boat Ramp and mouth of Snake River to Ice Harbor Dam.



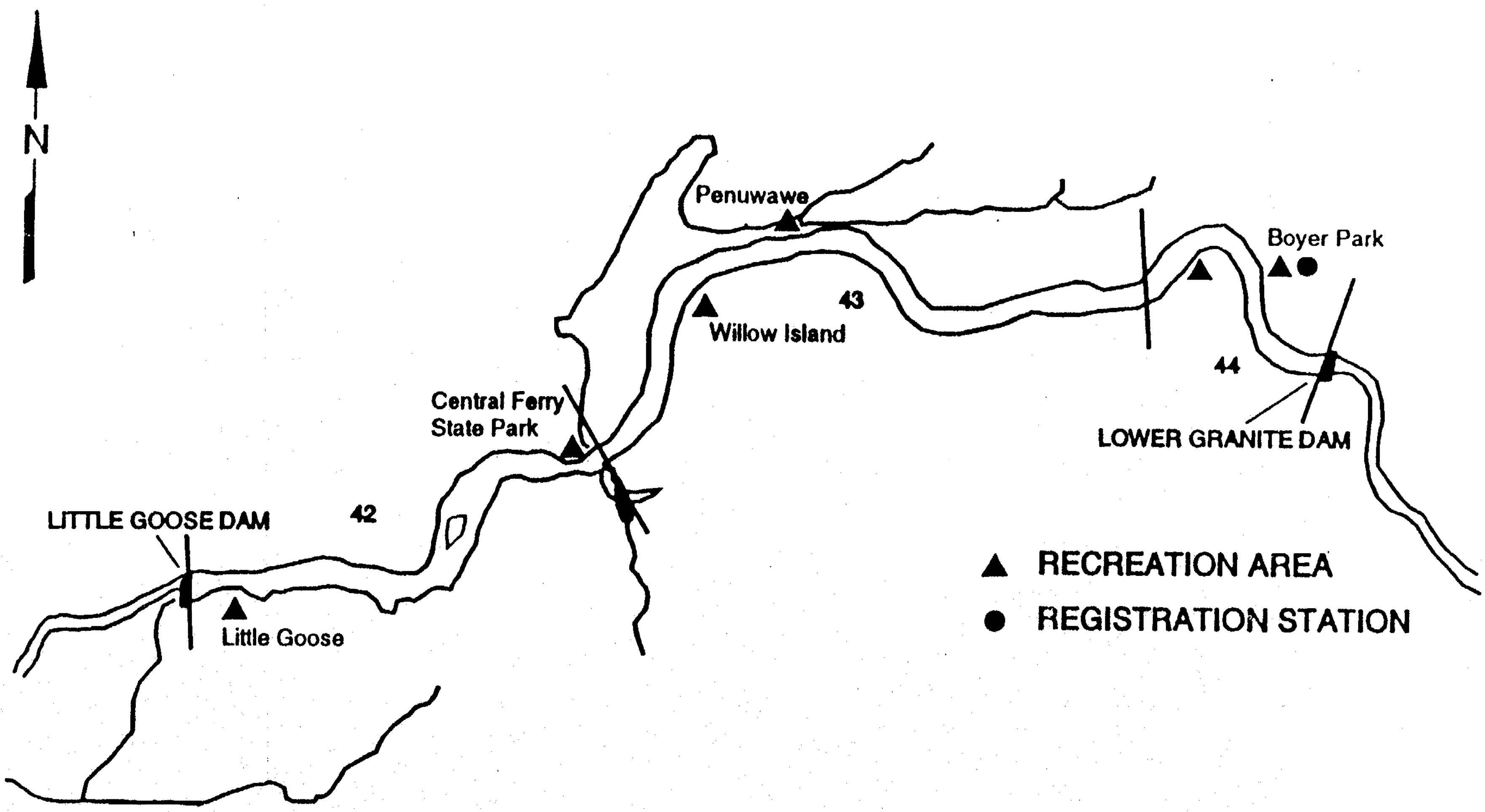
Appendix Figure A-7. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, Ringold Boat Ramp to Priest Rapids Dam.



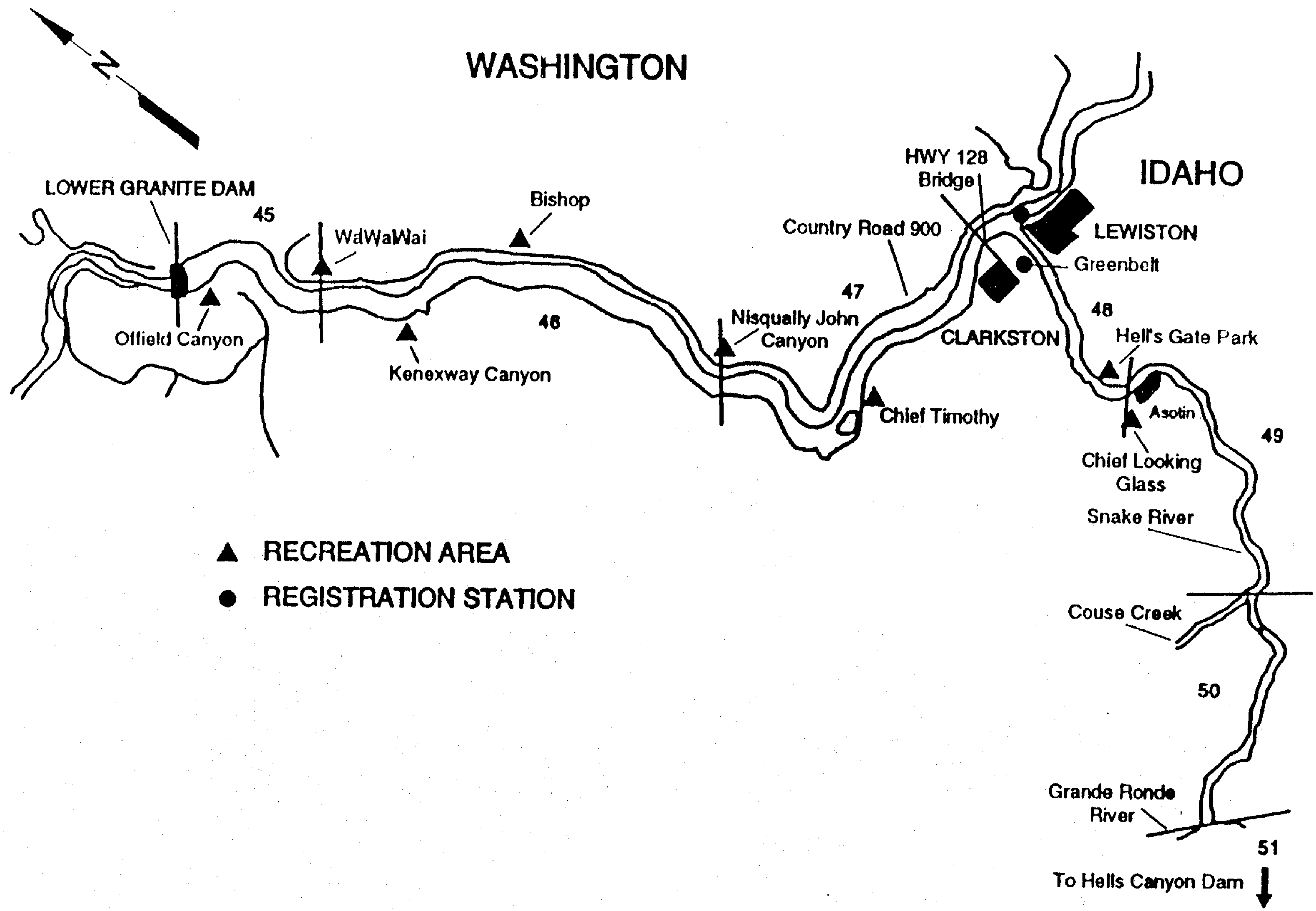
Appendix Figure A-8. 1993 Northern Squawfish Sport-Reward Fshery fishing location codes, Ice Harbor Dam to Lower Monumental Dam.



Appendix Figure A-9 993 Northern Squawfish Sport-Reward Fishery fishing location codes, Lower Monumental Dam to Little Goose Dam.



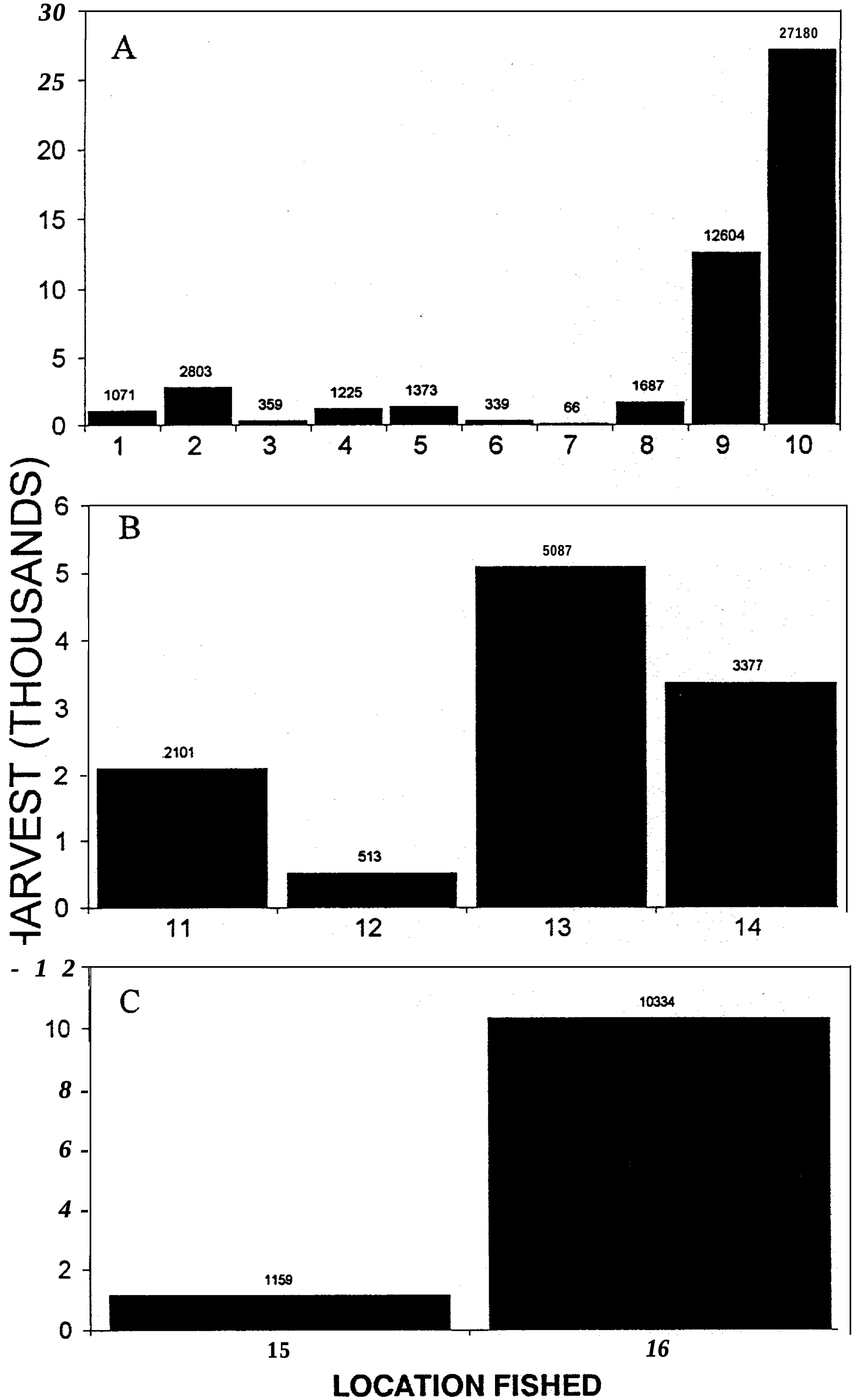
Appendix Figure A-10. 1993 Northern Squawfish Sport-Reward Fishery fishing locat codes, Little Goose Dam to Lower Granite Dam.



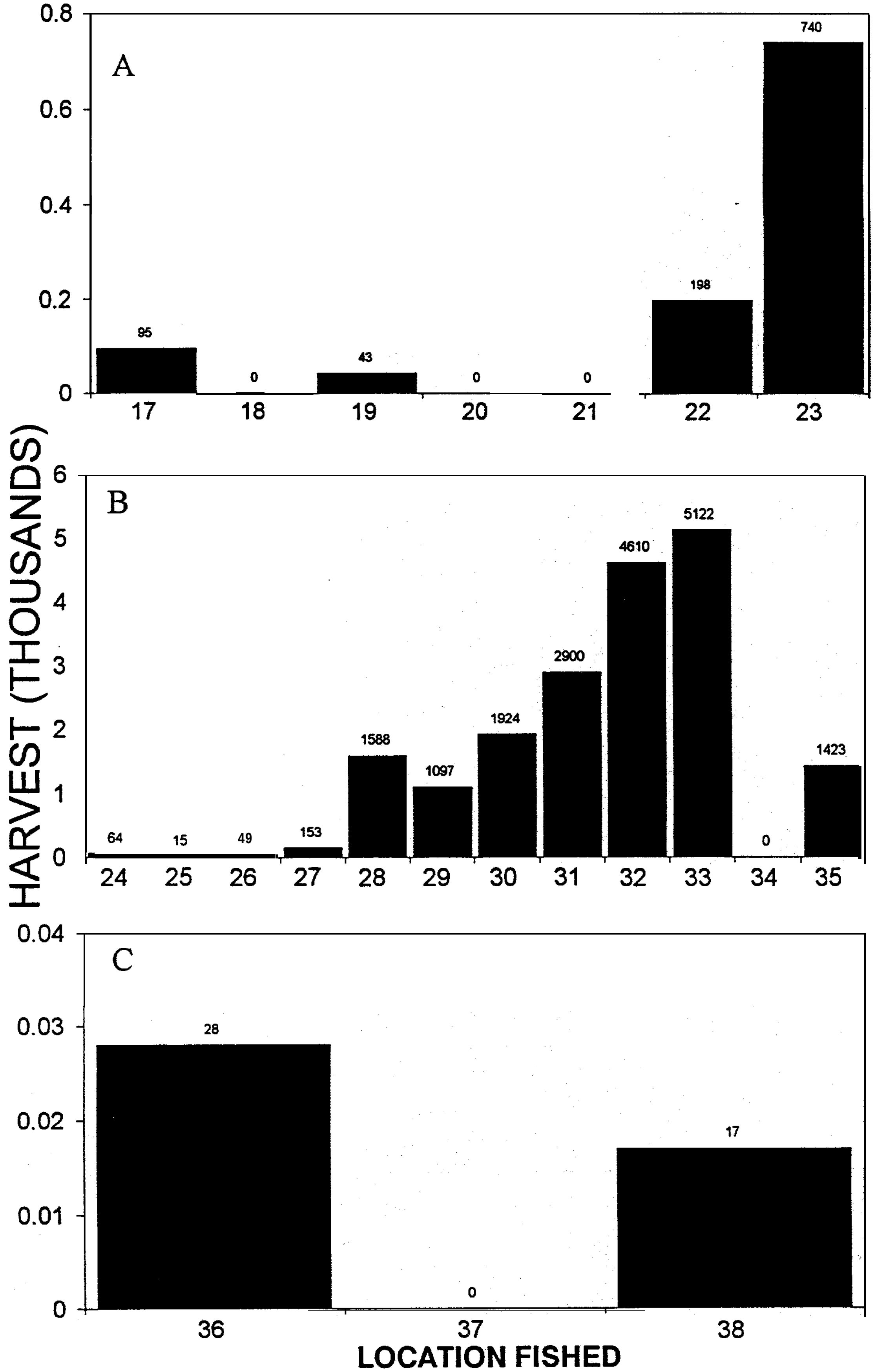
Appendix Figure A-11. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, Lower Granite Dam to Hells Canyon Dam.

APPENDIX B

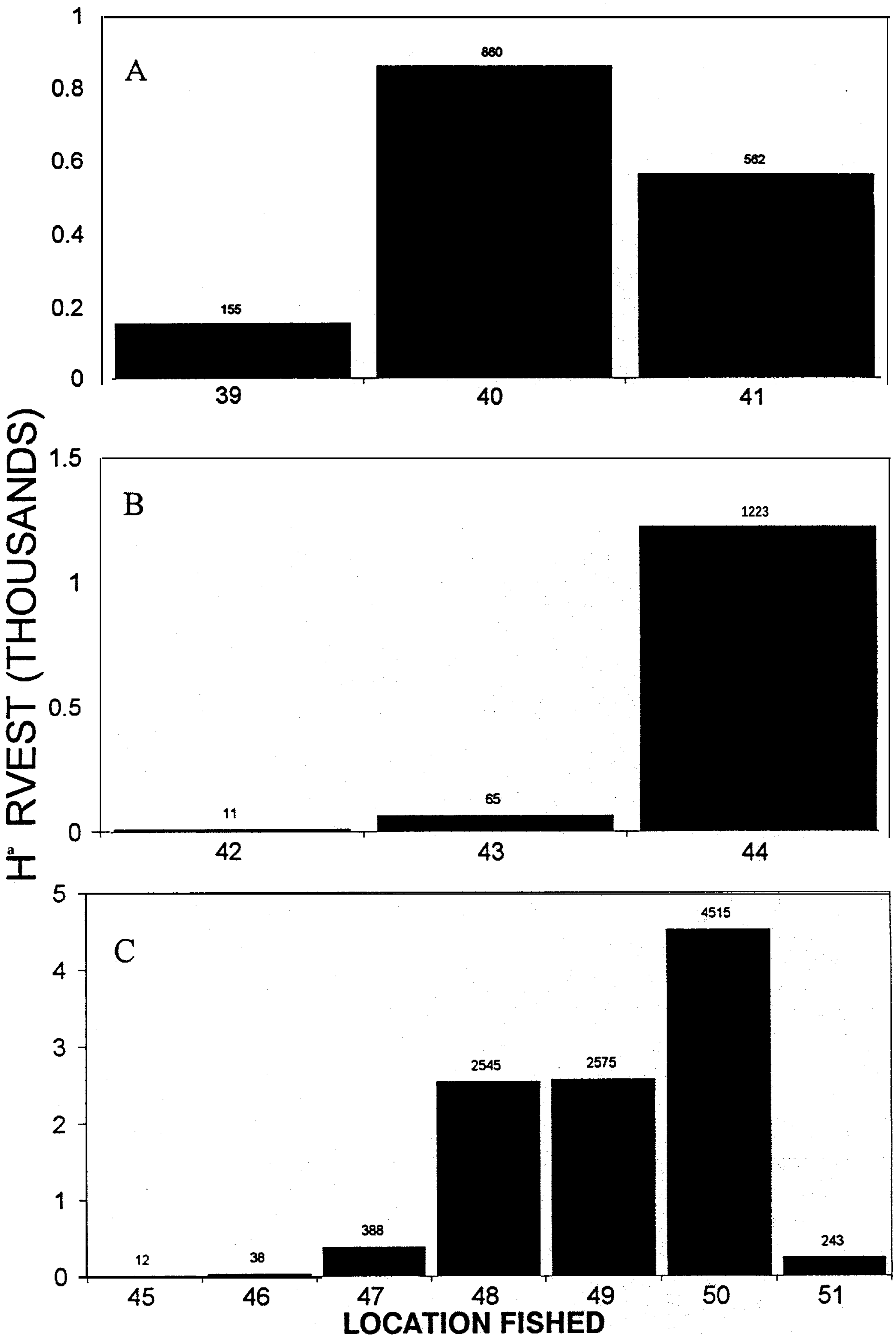
Bar Charts of Fishing Location Data by Reservoir



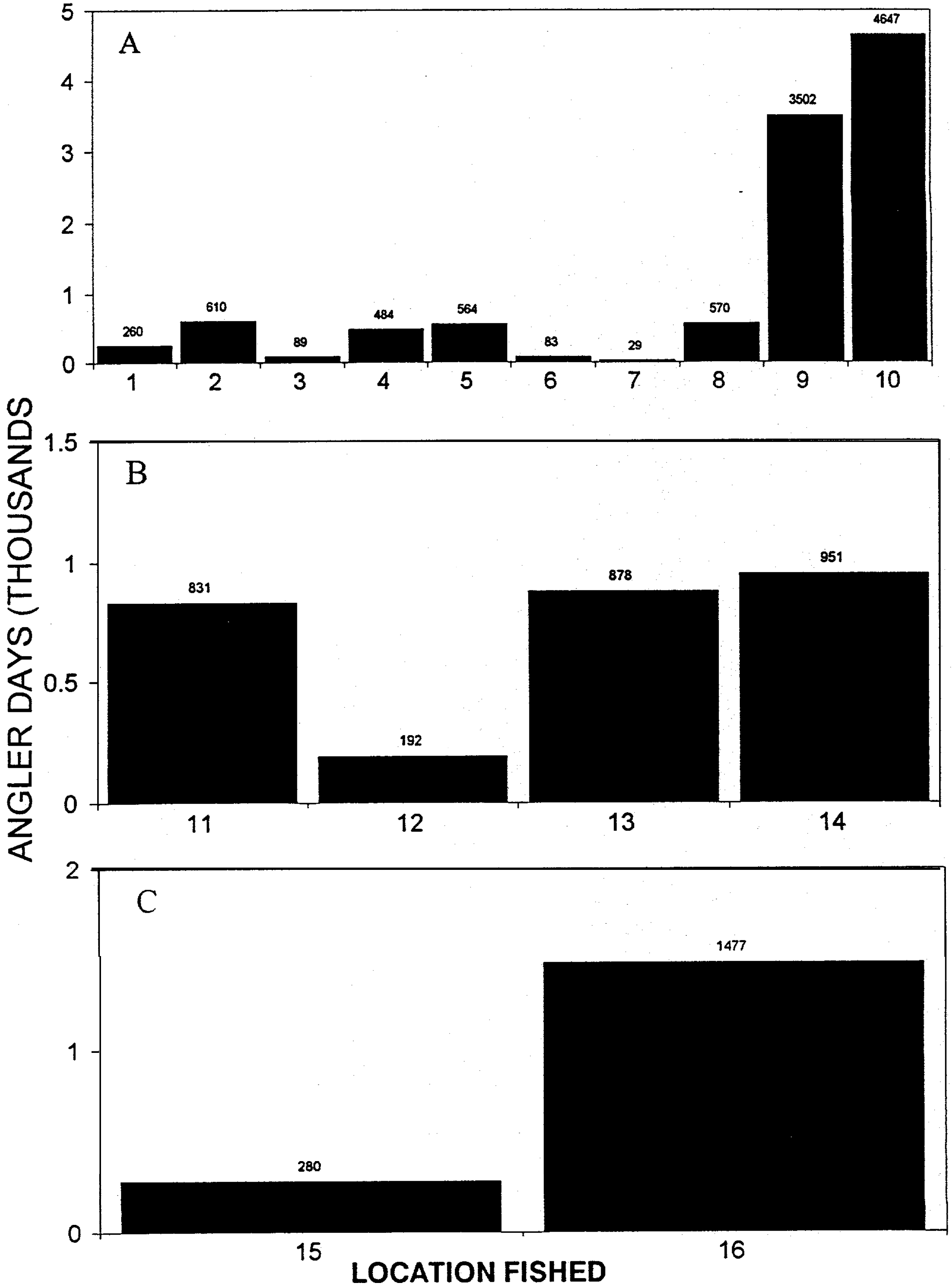
Appendix Figure B-1. Northern squawfish harvest by reservoir and location fished; A - Bonneville Tailrace, B - Bonneville Reservoir, C - The Dalles Reservoir. (Numbers above the bar represent the number of northern squawfish harvested). Please note the difference in scales.



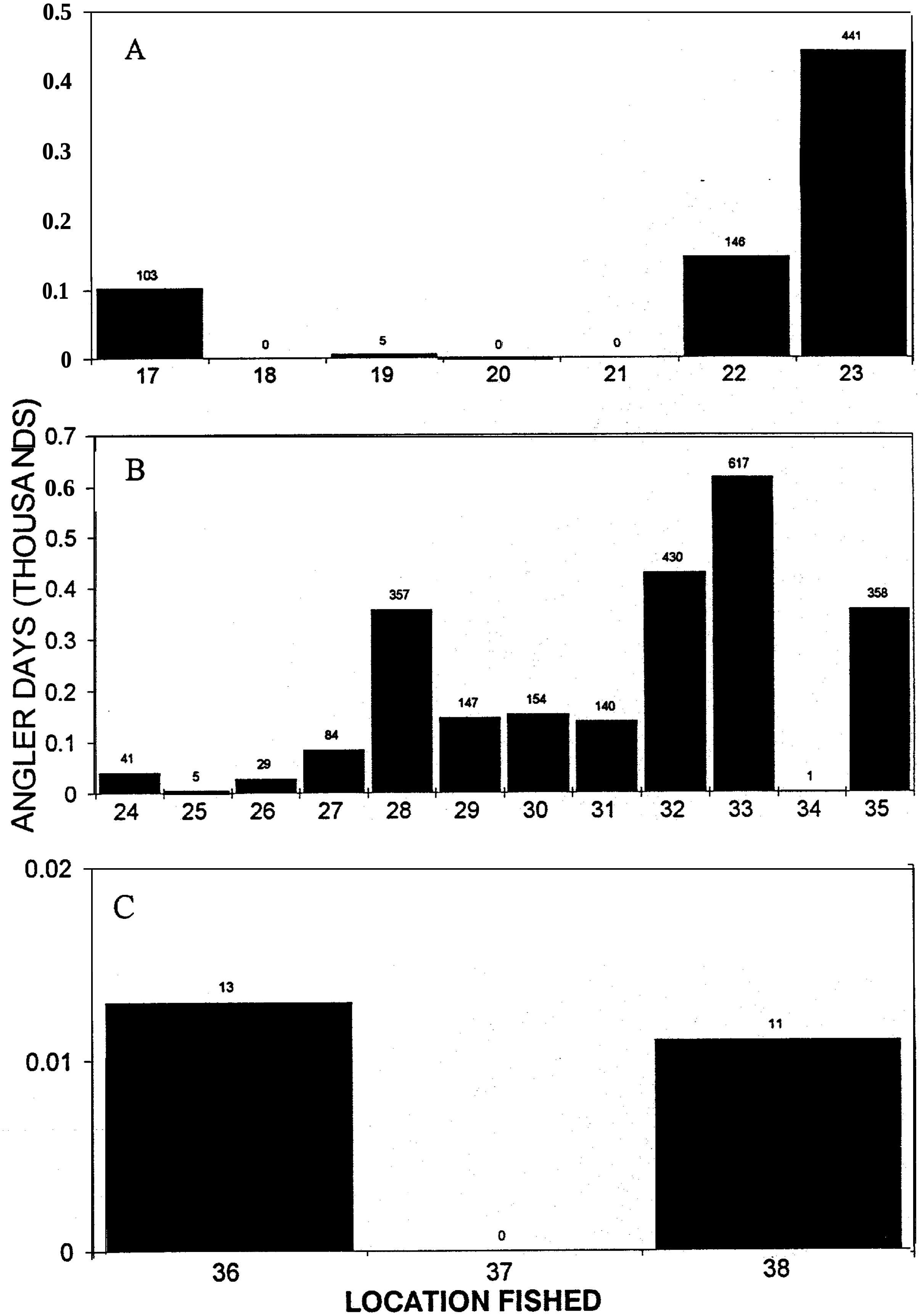
Appendix Figure B-2. Northern squawfish harvest by reservoir and location fished; A - John Day Reservoir, B - McNary Reservoir, C - Ice Harbor Reservoir. (Numbers above the bar represent the number of northern squawfish harvested). Please note the difference in scales.



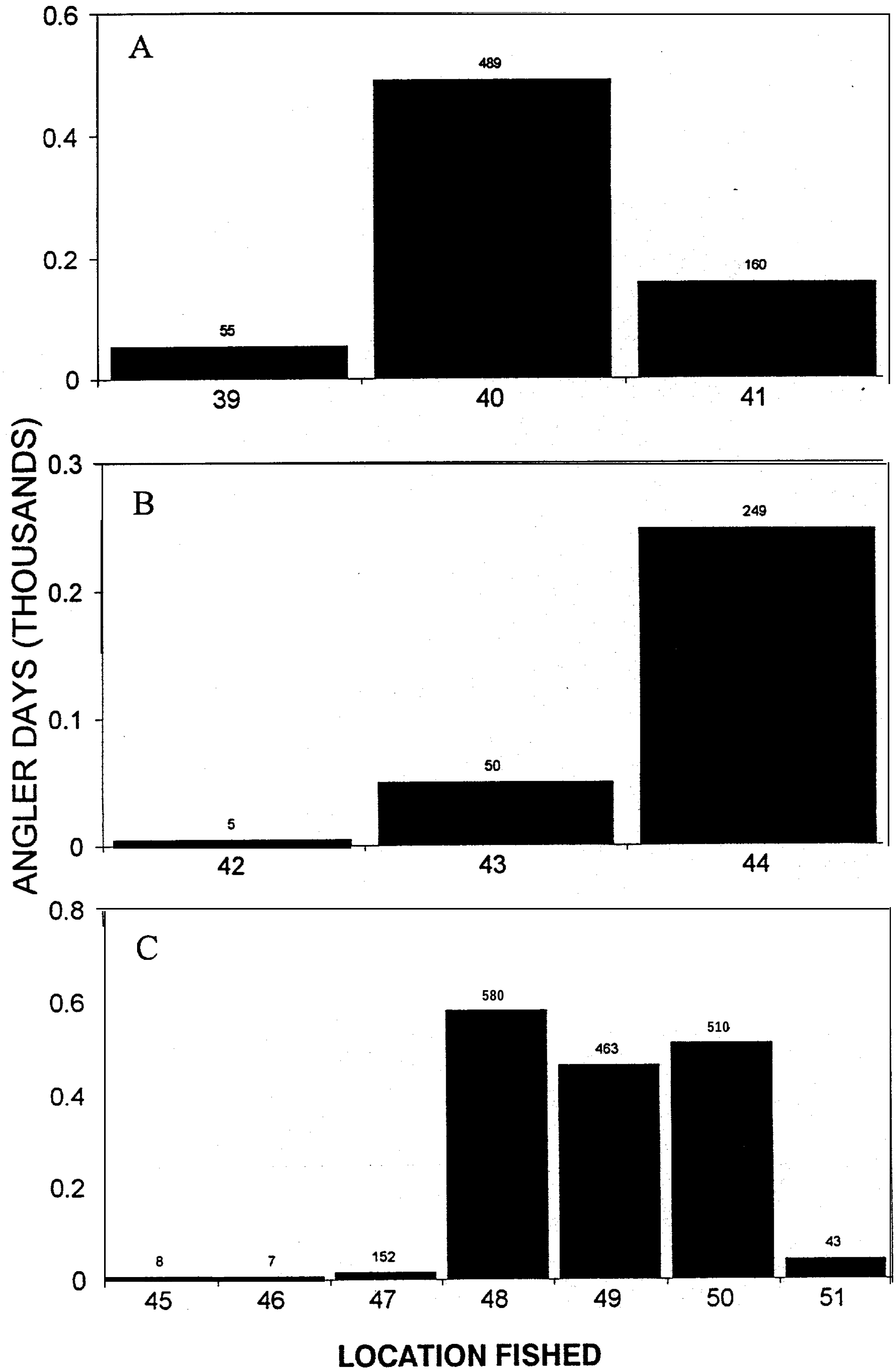
Appendix Figure B-3. Northern squawfish harvest by reservoir and location fished; A - Lower Monumental Reservoir, B - Little Goose Reservoir, C - Lower Granite Reservoir. (Numbers above the bar represent the number of northern squawfish harvested). Please note the difference in scales.



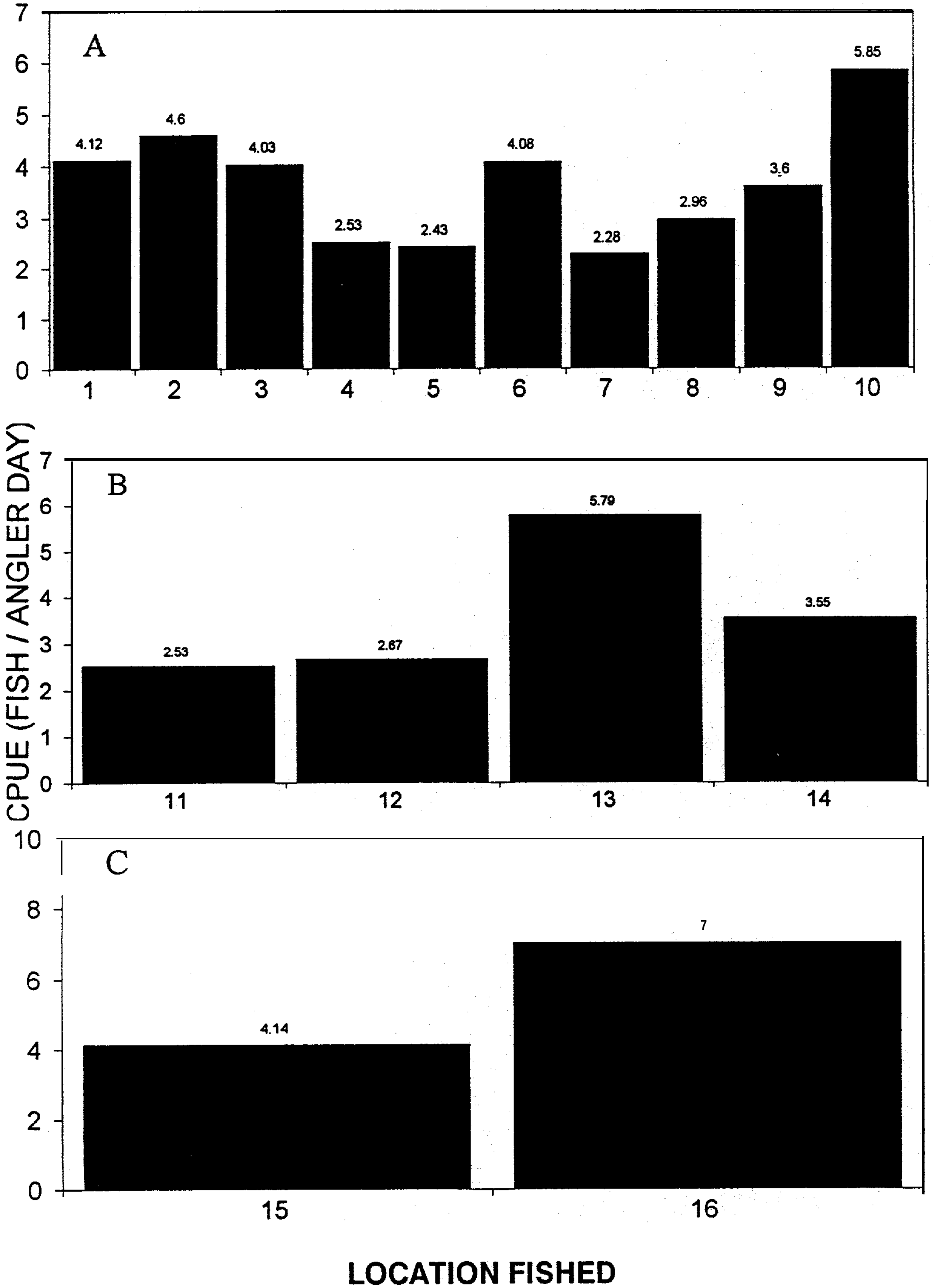
Appendix Figure B-4. Effort (angler days) by reservoir and location fished; A - Bonneville Tailrace, B - Bonneville Reservoir, C - The Dalles Reservoir. (Numbers above the bar represent the number of angler days). Please note the difference in scales.



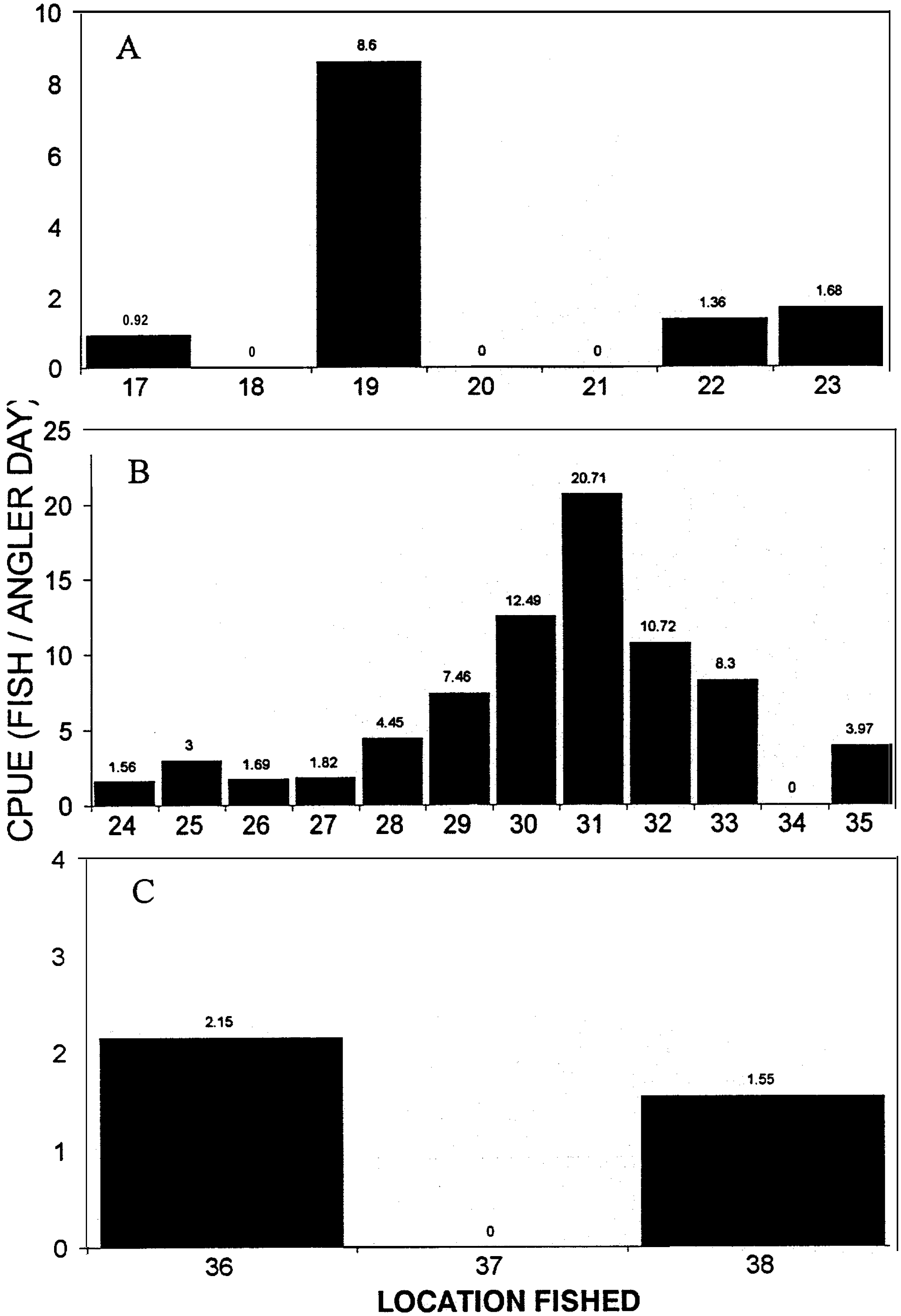
Appendix Figure B-5. Effort (angler days) by reservoir and location fished; A - John Day Reservoir, B - McNary Reservoir, C - Ice Harbor Reservoir. (Numbers above the bar represent the number of angler days). Please note the difference in scales.



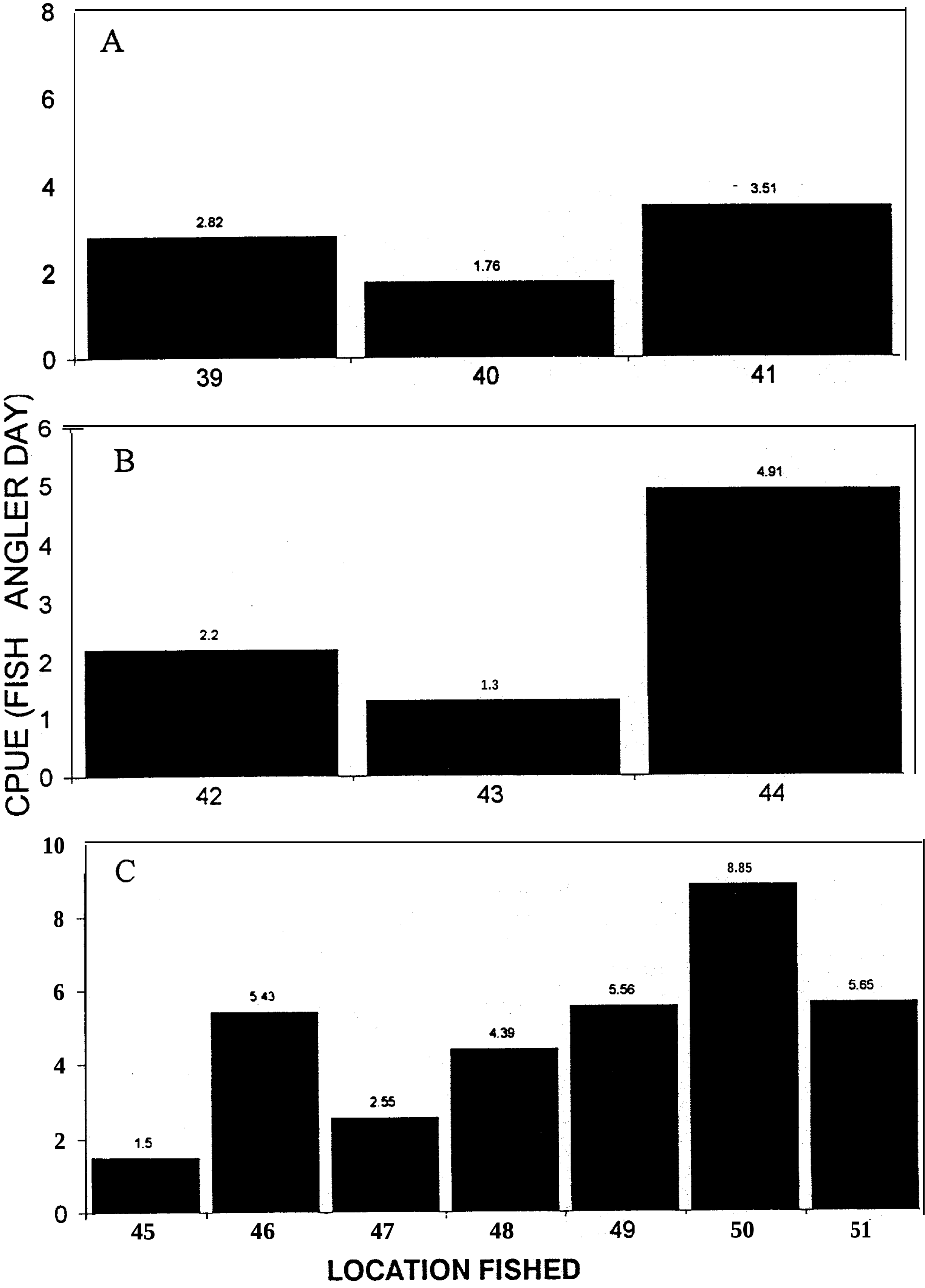
Appendix Figure B-6. Effort (angler days) by reservoir and location fished; A - Lower Monumental Reservoir, B - Little Goose Reservoir, C - Lower Granite Reservoir. (Numbers above the bar represent the number of angler days). Please note the difference in scales.



Appendix Figure B-7. CPUE (fish / angler day) by reservoir and location fished; A - Bonneville Tailrace, B - Bonneville Reservoir, C - The Dalles Reservoir. (Numbers above the bar represent the catch per unit effort). Please note the difference in scales.



Appendix Figure B-8. CPUE (fish / angler day) by reservoir and location fished; A - John Day Reservoir, B - McNary Reservoir, C - Ice Harbor Reservoir. (Numbers above the bar represent the catch per unit effort (fish / angler day)). Please note the difference in scales.



Appendix Figure B-9. CPUE (fish / angler day) by reservoir and location fished; A - Lower Monumental Reservoir, B - Little Goose Reservoir, C - Lower Granite Reservoir. (Numbers above the bar represent the catch per unit effort (fish / angler day)). Please note the difference in scales.

APPENDIX C

Telephone Survey: Estimated Catch and General Fishing Information Gathered From Northern Squawfiih Sport-Reward Fishery Anglers Who did not Report the Results of a Fishing Trip

Abstract

A random sample of anglers that registered with the 1993 northern squawfish sport-reward fishery and did not return to report the days catch were surveyed by telephone. Surveyed anglers cited poor success in catching northern squawfish large enough to be eligible for a $3 reward payment for not returning to the registration station to report the days catch. The survey estimated 24,731 northern squawfish, too small to qualify for the $3 reward, were caught by non-returning anglers. Approximately 48% of the 24,731 northern squawfish were returned to the water unharmed. The survey estimated that 2,968 northern squawfish, eligible for a $3 reward, were caught by non-returning anglers while only 19% were returned to the water unharmed. An estimated 4,146 smallmouth bass, 136 white sturgeon, 91 summer steelhead, 397 walleye and 11 chinook salmon were removed from the Columbia and Snake rivers by non-returning anglers. Catch estimates of fishes caught by non-returning anglers were not sufficiently high to indicate the sport-reward fishery was overexploiting any species. Approximately 95% of anglers surveyed cited helping to protect salmon as an important factor in motivating participation within the sport-reward fishery. The majority of anglers surveyed (77%) would have taken the fishing trip even if the sport-reward fishery did not exist, indicating that a majority of the fishing effort expended by non-returning anglers would have occurred without the sport-reward fishery.

A recall bias study was also conducted to determine if the anglers surveyed were accurately recalling the number of fish caught on a particular day. The estimated catch results were not shown to be significantly affected by the anglers ability to accurately recall the number of fish caught on a particular fishing trip.

Introduction

Northern squawfish are the dominant predator of juvenile salmonids in the lower Columbia and Snake River systems (Beamesderfer and Rieman 1991). Rieman and Beamesderfer (1990) used simulation modeling to demonstrate that predation on juvenile salmonids could be reduced to 50% with limited (10%-20%), but sustained exploitation of northern squawfish greater than 275 mm fork length. The Columbia River Northern Squawfish Management Program was created in 1990 to achieve the 10-20% exploitation of northern squawfish recommended by Rieman and Beamesderfer (1990). The northern squawfish sport-reward fishery was implemented within the lower Columbia and Snake River systems in 1991 as part of the Columbia River Northern Squawfish Management Program's effort to increase exploitation of northern squawfish greater than 275 mm total length. The sport-reward fishery offered a reward payment of $3 per northern squawfish greater than 275 mm total length. Anglers participating in the sport-reward fishery were required to register daily, prior to going fishing. A total of 18 sport-reward fishery registration Stations (Appendix Table C-l) were located on the Columbia and Snake rivers in 1993. Registered anglers were encouraged to return to the registration stations after fishing to complete an exit interview. The exit interview allowed sport-reward fishery technicians to collect data on the anglers catch. Anglers were issued a voucher in the exit interview, which enabled the angler to receive a $3 reward for each eligible northern squawfish. Anglers who registered with the program and did not return to complete an exit interview were referred to as "non-returning anglers." Data from previous years showed that approximately 60% (20,000) of the registered sport-reward fishery anglers were non-returning anglers. A similar telephone survey of non-returning sport-reward fishery anglers was conducted in 1992 by Dr. Susan Hanna at Oregon State University (Hanna et al. 1992). Some of the questions in this survey were taken from Hanna et al. (1992), but Dr. Hanna's study did not estimate the catch of non-returning anglers. The primary purpose of this study was to estimate non-returning angler's catch and ensure the sport-reward fishery was not causing overexploitation of any species of fish within the Columbia and Snake river systems. Other objectives of this study were to estimate why anglers participate in the sport-reward fishery, why anglers did not return to complete an exit interview, and the types of fishing gear used by anglers. Catch estimates from returning-angler data were also compared to catch estimates from the telephone survey data for the purpose of determining if the two methods produced similar estimates.

A recall bias study was also conducted for the purpose of determining if the answers given to telephone survey questions were accurate.

Telephone Survey Methods

Non-returning anglers surveyed in this report were contacted by telephone and asked to complete a questionnaire (Appendix Table C-2). A sample of non-returning anglers was generated weekly by random selection using a data base program. A stratified random sample was selected from the 18 registration stations and the total number of non-returning anglers to be sampled from each registration station was determined by the percentage of non-returning anglers registering at each registration station (Appendix Table C-l).

A maximum of five attempts were made to reach an angler by phone. If the initial attempt resulted in no answer, the angler was scheduled for a call on the next evening of interviews. The second attempt was scheduled for an evening call on the weekend. If after three attempts, no one had been reached, a morning attempt was scheduled. A fifth and final attempt was made in the afternoon before recording the angler as unreachable. The telephone calling schedule was adopted from the Social and Science Research Center at Washington State University (Dillman 1978).

Appendix Table C-l. Sample size and error bound by registration station for the number of anglers sampled in the telephone survey of non-returning anglers.

Registration Stations	Total Non-Returning Anglers	%Total[1]	Non-Returning Anglers Sampled	Error Bound[2]
1. CATHLAMET	862	4.36	76	0.110
2. RAINIER	678	3.43	60	0.124
3. KALAMA	1299	6.57	117	0.088
4. GLEASON	1354	6.85	121	0.087
5. CAMAS	1524	7.71	138	0.081
6. THE FISHERY	1116	5.60	101	0.095
7. HAMILTON I.	1216	6.15	99	0.096
8. CASCADE L.	693	3.51	61	0.123
9. BINGEN	779	3.94	69	0.116
10. THE DALLES	881	4.46	76	0.110
11. LEPAGE	923	4.67	73	0.112
12. UMATILLA	789	3.99	72	0.116
13. COLUMBIA PT.	942	4.77	85	0.104
14. VERNITA	1127	5.70	100	0.096
15. HOOD PARR	1488	7.53	133	0.083
16. LYONS FERRY	775	3.92	65	0.119
17. BOYER PARR	716	3.62	65	0.120
18. GREENBELT	2596	1.31	233	0.063
TOTALS	19,758	100	1744	0.023

1 The percentage of non-returning anglers registering at each registration station.
2 Error bound was estimated weekly to assist in determining the adequacy of the sample size using $p=.5$ and $q=.5$.

Appendix Table C-2, Telephone questionnaire for non-returning anglers for the northern squawfish sport-reward fishery 1993.

Q1. How well do you remember the events of your fishing trip on (date)?

1. **Very** well
2. Moderately well
3. Not well (I only have a few questions and perhaps they will refresh your memory.)

We have created maps that divide the Columbia and Snake rivers into large sections. These maps will help us to determine the effect our program is having on the fish populations in those areas. We are not trying to locate your favorite fishing hole. I just need to know approximately where you were fishing that day.

Q2. Reservoir Code _______

Q2A. Location Code _______

Q3. What were the top three species that you were fishing for that day?

A. _____ **B.** _____ **C.** _____

Q4. What is your best estimate of the number of hours that you fished for northern squawfish that day? (If 0 go to Q7)

___ **HRS.**

Were you targeting northern squawfish the entire time?

Q5. Did you catch any fish while you were fishing for northern squawfish?

0. DID NOT REMEMBER 9. DID NOT FISH
1. YES ___ **2. NO** ___ (If no go to **Q7)**

If yes: Please estimate what species you caught and how many of each? Please tell me one species at a time so that I can record them.

Q6A. Were the northern squawfish over or under 11 inches?
(> = 11 inches NSF-G) (*c* 11 inches NSF-L)

Appendix Table C-2. Continued.

Q6. **SPECIES** **Q6B. QUANTITY**

_____	_____
_____	_____
_____	_____

Q6C. What did you do with the fish? Did you:

1. Return them to the water unharmed.
2. Kill them and return them to the water.
3. Keep them to eat.
4. Keep them for other uses.
5. Return them to the registration site.
6. Other **Q6D.** Memo

Q7. Please estimate how many hours you fished for species other than northern squawfish? **(If 0 go to Q9)**

___ HRS.

Were you targeting other species the entire time?

QS. Did you catch any fish while you were fishing for other species?

0. **DID NOT REMEMBER** **9. DID NOT FISH**
1. YES ___ **2. NO ___** (If no go to **Q10)**

If yes: Please estimate what species you caught and how many of each?
Please tell me one species at a time so that I can record them.

Q9A. Were the northern squawfish over or under 11 inches?
(> = 11 inches NSF-G) **(<** 11 inches NSF-L)

Q9. **SPECIES** **Q9B. QUANTITY**

_____	_____
_____	_____
_____	_____

Appendix Table C-2. Continued.

Q9C. What did you do with the fish? Did you:

1. Return them to the water unharmed.
2. Kill them and return them to the water.
3. Keep them to eat.
4. Keep them for other uses.
5. Return them to the registration site.
6. Other **Q9D.** Memo

Q10. Did you fish from:

1. Boat
2. Shore
3. **Both**

What type of fishing gear did you use?

	YES	NO
Q11A. Trolling lures	1	2
Q11B. Casting bait	1	2
Q11C. Casting lures	1	2

Q11D. Other (If no on llA,B and C)

412. What was the main reason that you did not return to the registration site?

1. You had no fish to turn in.
2. There were not enough fish to make returning worthwhile.
3. All northern squawfish caught were under 11".
4. Other reasons: **Q12A.** Please explain:__________

I am going to read a list of reasons that people participate in the northern squawfish program, As I read each one, please tell me how important it is to you.

	VERY	**SOMEWHAT**	**NOT**
Q13A Payment for northern squawfish	1	2	3
Q13B Recreational opportunity	1	2	3
Q13C Opportunity to cover expenses while targeting game species	1	2	3
Q13D Helping to protect salmon	1	2	3

414. Are the check stations
conveniently located for you?
1 YES **2 N 0**

Q14A If no: What new locations would you suggest?

Q15. Do you plan to register again with the program?

1 YES **2 N 0**

Q15A If no: What is the main reason you do not plan to register with the program? (Wait for a response and then categorize)

1. Poor success catching northern squawfish.
2. Registration is too much trouble.
3. Too far to registration site.
4. Other reasons: **Q15B** Please explain: ________

Q16 Would you have taken this fishing trip if the sport reward program did not exist?

1 YES **2 N 0**

Q17 How would you rate your interaction with the technicians at the check station?

1. Very good
2. Good
3. Poor (Record comments on all number 3 responses)

Q17A Comments

A data base program was created that contained fields to record answers from each phone survey question (Appendix Table C-2). The data was checked for errors using a program designed to detect non-relevant responses in each field.

Northern squawfish, smallmouth bass, white sturgeon, summer steelhead, walleye, and chinook salmon were used to compare phone survey proportional estimates (the number of fish removed by phone survey anglers/the number of phone survey anglers x the total number of non-returning anglers) and returning anglers proportional estimates (the number of fish removed by returning anglers/the number of returning anglers x the total number of non-returning anglers) of the number of fish caught by non-returning anglers. The statistically significant difference between phone survey estimates and returning angler estimates was not calculated.

The returning anglers sampled in the recall bias study were randomly selected from the sport-reward fishery data base. The selected anglers were contacted by telephone and asked a series of questions (Appendix Table C-3) that required the recollection of questions previously answered by returning anglers during the exit interview. The recall bias survey responses were compared to the exit interview responses at 2-, 4-, 6-, 8-, 10- and 12-week intervals from the time of registration until the day the angler was surveyed. The number of northern squawfish over and under 11 inches total length were used in our data analysis. The answer given by an angler during the exit interview was subtracted from the answer given in the recall bias study. A value of zero would indicate the angler recalled exactly the number of fish recorded on the anglers exit interview. A positive value meant the angler remembered catching more fish than were recorded on the exit interview and a negative value meant the angler remembered catching less fish. For example, if an angler recorded a catch of five northern squawfish in the exit interview and three northern squawfish in the recall bias survey, then the angler's recall bias score would be -2 fish.

Anglers were also asked how well they remembered the events of a fishing trip and allowed to respond either "very well," "moderately well" or "not well" (Appendix Table C-3). A general linear model was used to test for significant differences in the accuracy of angler responses among the various week intervals (using recall bias scores) and among the three possible responses for how well anglers remembered the fishing trip (Appendix Table C-3). The general linear model test was considered significant at $p < .05$.

Appendix Table C-3, Northern squawfish sport-reward program recall bias study questions,

---

Q1. How well do you remember the events of your fishing trip on (Day and Date)?

1. **Very** well
2. Moderately well
3. Not well (I only have a few questions and perhaps they will refresh your memory).
4. Unable to recall the fishing trip **and** cannot complete the questionnaire (Only use when angler cannot respond to the questions).

Q2. What were the top three species that you fished for that day?

A. ____ **B.** ____ C.____

Q3. Give me your best estimate of how many hours you fished that day? Please estimate to the nearest quarter hour.

Hours

Q4. I have a map of the Columbia and Snake Rivers. Could you tell me approximately where you were fishing that day?

Location code

Give me your best estimate of how many northern squawfish you returned to the check station?

Q5. ___ **# Over 11 inches** **Q6.** __ **# Under 11 inches**

Q7. Did you fish from:

1. Boat 2. Shore 3. Both

Results

Phone Survey Results

The majority (58%) of anglers surveyed fished from shore. Fresh bait was more commonly used by anglers (82%) than either trolling (13 %) or casting lures (47 %).

Approximately 96% of the non-returning anglers surveyed did not return to the check stations because they had no fish eligible for the reward (Appendix Table C-4). The remaining 4% (78 non-returning anglers) either gave their northern squawfish catch to other anglers to return to the check station or did return the catch to the registration station, but did not complete an exit interview.

Questions Q13A, B, C and D (Appendix Table C-2) address why people participate in the sport-reward fishery. Payment for northern squawfish was at least somewhat important to 77% of the non-returning anglers surveyed. The recreational opportunity offered by the sport-reward fishery was attractive to 89% of the surveyed anglers, but 95 % of the non-returning anglers sampled wanted to protect the salmon (Appendix Table C-4).

Angler satisfaction with the administration of the sport-reward program was high. The registration stations were conveniently located for 84% of all anglers surveyed. The majority (94%) of non-returning anglers sampled plan to register with the program again while the remaining would not continue in the fishery and cited poor catch and not enough time as major reasons for discontinuing participation in the program. Non-returning anglers rated interaction with the check station technicians to be “very good” or “good” in 99% of the surveys.

Anglers targeting northern squawfish had smaller catches of other species of fish, since northern squawfish composed 34% of the total catch for non-returning anglers who targeted northern squawfish (Appendix Table C-5), but composed only 13% of the total catch of non-returning anglers who did not target them (Appendix Table C-6). Anglers who targeted northern squawfish caught smallmouth bass (17%) and peamouth (11.5 %) more frequently than other species of fish, except for northern squawfish.

Appendix Table C-4. Frequency of angler responses to categorized questions asked in the 1993 telephone survey.

Q#[1]	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Q1				
1	713	40.9	713	40.9
2	588	33.7	1301	74.6
3	443	25.4	1744	100.0
Q2				
1	711	40.8	711	40.8
2	185	10.6	896	51.4
3	61	3.5	957	54.9
4	101	5.8	1058	60.7
5	316	18.1	1374	78.8
6	9	0.5	1383	79.3
7	63	3.6	1446	82.9
8	66	3.8	1512	86.7
9	232	13.3	1744	100.0
Q2A				
1[2]	7	0.4	7	0.4
2	119	6.8	126	7.2
3	8	0.5	134	7.7
4	6	0.3	140	8.0
5	114	6.5	254	14.6
6	2	0.1	256	14.7
7	3	0.2	259	14.9
8	78	4.5	337	19.3
9	147	8.4	484	27.8
10	232	13.3	716	41.1
11	48	2.8	764	43.9
12	22	1.3	786	45.1
13	49	2.8	835	47.9
14	62	3.6	897	51.5
15	11	0.6	908	52.1
16	52	3.0	960	55.1
17	30	1.7	990	56.8
22	3	0.2	993	57.0
23	64	3.7	1057	60.7
24	4	0.2	1061	60.9
25	3	0.2	1064	61.1
26	1	0.1	1065	61.1
27	43	2.5	1108	63.6

[1] Refer to Appendix Table D-l for the questions represented by each code as well as the meaning of each response.
[2] Appendix Tables A-l through A-11 show the area of the Columbia or Snake rivers represented by each number.

Appendix Table C-4. Continued.

Q#	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Q2A (Continued)				
28	24	1.4	1132	65.0
29	25	1.4	1157	66.4
30	8	0.5	1165	66.9
31	2	0.1	1167	67.0
32	2	0.1	1169	67.1
33	87	5.0	1256	72.1
34	1	0.1	1257	72.2
35	113	6.5	1370	78.6
36	8	0.5	1378	79.1
38	2	0.1	1380	79.2
40	51	2.9	1431	82.1
41	12	0.7	1443	82.8
42	2	0.1	1445	83.0
44	64	3.7	1509	86.6
45	3	0.2	1512	86.8
46	4	0.2	1516	87.0
47	18	1.0	1534	88.1
48	101	5.8	1635	93.9
49	89	5.1	1724	99.0
50	18	1.0	1742	100.0
Q3A				
AMS[3]	31	1.8	31	1.8
C	9	0.5	40	2.3
CC	93	5.3	133	7.6
CK	2	0.1	135	7.7
CP	1	0.1	136	7.8
LCH	1	0.1	137	7.9
LMB	9	0.5	146	8.4
NSF[4]	1054	60.4	1200	68.8
RU	19	1.1	1219	69.9
SA	15	0.9	1234	70.8
SK	2	0.1	1236	70.9
SMB	278	15.9	1514	86.8
SS	46	2.6	1560	89.4
TR	3	0.2	1563	89.6
WAL	47	2.6	1611	92.3
WS	129	7.4	1739	99.7
YP	5	0.3	1744	100.0

[3] Refer to Appendix Table D-l for a list of fish species represented by each code.
[4] Northern squawfish.

Appendix Table C-4. Continued.

Q#	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Q3B				
RU	1	0.1	1	0.1
AMS	14	1.6	16	1.8
BG	3	0.3	19	2.2
BH	1	0.1	20	2.3
C	15	1.7	35	4.0
cc	92	10.6	127	14.6
CK	2	0.2	129	14.8
CMO	1	0.1	130	14.9
CP	2	0.2	132	15.2
LMB	12	1.4	144	16.5
NSF	275	31.6	419	48.1
PMO	3	0.3	422	48.5
RU	26	3.0	448	51.4
SA	12	1.4	460	52.8
SK	2	0.2	462	53.0
SMB	237	27.2	699	80.3
SNB	1	0.1	700	80.4
SP	1	0.1	701	80.5
ss	36	4.0	736	84.5
TR	1	0.1	737	84.6
WAL	57	6.5	794	91.2
ws	59	6.8	853	97.9
YBH	1	0.1	854	98.0
YP	17	2.0	871	100.0
Q3C				
C	1	0.2	1	0.2
SM	1	0.2	2	0.5
AMS	8	1.8	10	2.3
BG	3	0.7	13	2.9
C	17	3.9	30	6.8
cc	49	11.1	79	17.9
CK	5	1.1	84	19.0
CP	2	0.5	86	19.5
LMB	9	2.0	95	21.5
NSF	173	39.2	268	60.8
PMO	1	0.2	269	61.0
RU	17	3.9	286	64.9
SA	5	1.1	291	66.0
SK	2	0.5	293	66.4
SMB	67	15.2	360	81.6
ss	15	3.4	375	85.0
TR	1	0.2	376	85.3
WAL	27	6.1	403	91.4
ws	23	5.2	426	96.6
YP	15	3.4	441	100.0

Appendix Table C-4. Continued.

Q#	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Q5				
0	34	2.0	34	2.0
1	757	43.5	791	45.4
2	478	27.5	1269	72.9
9	472	27.1	1741	100.0
Q6C AND Q9C				
1	1287	65.0	1287	65.1
2	206	10.4	1494	75.5
3	297	15.0	1791	90.5
4	109	5.5	1900	96.0
5	64	3.2	1964	99.2
6	16	0.8	1980	100.0
Q8				
0	36	2.1	36	2.1
1	429	24.6	465	26.7
2	254	14.6	719	41.3
9	1022	58.7	1741	100.0
Q10				
1	673	38.6	673	38.6
2	1015	58.3	1688	96.9
3	54	3.1	1742	100.0
Q11A				
1	219	12.6	219	12.6
2	1525	87.4	1744	100.0
Q11B				
1	1435	82.3	1435	82.3
2	309	17.7	1744	100.0
Q11C				
1	814	46.7	814	46.7
2	930	53.3	1744	100.0
Q12				
1	935	53.7	935	53.7
2	360	20.7	1295	74.3
3	369	-21.2	1664	95.5
4	78	4.5	1742	100.0
Q13A				
1	693	39.7	693	39.7
2	651	37.3	1344	77.1
3	400	22.9	1744	100.0

Appendix Table C-4. Continued.

Q#	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Q13B				
1	1190	68.2	1190	68.2
2	364	20.9	1554	89.1
3	190	10.9	1744	100.0
Q13C				
1	567	32.5	567	32.5
2	435	24.9	1002	57.5
3	742	42.5	1744	100.0
Q13D				
1	1460	83.7	1460	83.7
2	201	11.5	1661	95.2
3	83	4.8	1744	100.0
Q14				
1	1469	84.2	1469	84.2
2	275	15.8	1744	100.0
Q15				
1	1637	93.9	1637	93.9
2	107	6.1	1744	100.0
Q15A				
1	23	23.2	23	23.2
2	8	8.1	31	31.3
3	9	9.1	40	40.4
4	59	59.6	99	100.0
Q16				
1	1332	76.5	1332	76.5
2	410	23.5	1742	100.0
Q17				
1	1410	80.9	1410	80.9
2	317	18.2	1727	99.1
3	15	0.9	1742	100.0

The sport-reward fishery non-returning anglers were shown to have increased angler effort in the Columbia and Snake rivers only by a small amount, since the majority of the anglers surveyed (77%) would have taken the fishing trip even if the sport-reward fishery did not exist (Appendix Table C-4). Fish caught most frequently by anglers who would have taken the fishing trip even if the sport-reward fishery did not exist were smallmouth bass (25.7%), northern squawfish (24%), peamouth (8.9%) and white sturgeon (8.7%; Appendix Table C-7). The fish caught most frequently by anglers who would not have taken the fishing trip if the sport-reward fishery did not exist were northern squawfish (38.5%), smallmouth bass (14.7%), peamouth (10.7%) and white sturgeon (5.7%; Appendix Table C-8). Anglers, who would have been fishing regardless of the sport-reward fishery's existence, caught 82% of all fish caught by non-returning anglers.

The phone survey catch estimate for northern squawfish under 11 inches (12,825) and the returning angler catch estimates (10,171) were more similar than estimates of other fishes (Appendix Table C-9). Phone survey catch estimates for smailmouth bass (4,146) were approximately six times larger than returning angler estimates (644). Since returning angler catch estimates were lower than phone survey catch estimates for all species of fish tested (Appendix Table C-9), no further test of statistical significance was required to make the management decision to continue using the phone survey for estimating the catch of non-returning anglers.

Non-returning anglers total catch of northern squawfish under 11 inches was estimated to be 24,731 fish (+/- 4,761 fish- 95% confidence intervals). Anglers returned 48% of the 24,73 1 northern squawfish under 11 inches to the water unharmed (Appendix Table C-10). The percentage of northern squawfish under 11 inches returned to the water unharmed ranged from 11% to 89 % among registration stations.

The non-returning anglers estimated catch of northern squawfish over 11 inches was 2,968 (+/- 1,222 fish-95% confidence intervals). Nineteen percent were returned to the water unharmed. The percentage of northern squawfish over 11 inches returned to the water unharmed ranged from 0% to 100% among registration stations (Appendix Table C-11).

Appendix Table C-5. Frequency of fish species caught by anglers while targeting northern squawfish.

Species[1] Codes	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AMS	23	0.4	31	0.5
BG	19	0.3	50	0.9
BH	317	5.5	367	6.4
BLB	1	0.0	368	6.4
BT	2	0.0	370	6.5
C	185	3.2	555	9.7
CC	187	3.3	742	12.9
CCT	10	0.2	752	13.1
CF	1	0.0	753	13.1
CK	1	0.0	754	13.1
CMO	52	0.9	806	14.1
COT	92	1.6	898	15.7
CP	73	1.3	971	16.9
CR	3	0.1	974	17.0
CT	1	0.0	975	17.0
LCH	91	1.6	1066	18.6
LMB	10	0.2	1076	18.8
LW	1	0.0	1077	18.8
NSF	1972	34.4	3049	53.2
PGW	6	0.1	3055	53.3
PMO	660	11.5	3715	64.8
RS	50	0.9	3765	65.6
RU	46	0.8	3811	66.5
S	5	0.1	3816	66.5
SA	15	0.3	3831	66.8
SF	34	0.6	3865	67.4
SH	6	0.1	3871	67.5
SK	434	7.6	4305	75.1
SMB	974	17.0	5279	92.0
SP	7	0.1	5286	92.2
SS	11	0.2	5297	92.4
TR	3	0.1	5300	92.4
WAL	32	0.6	5332	93.0
WF	1	0.0	5333	93.0
WS	310	5.4	5643	98.4
YBH	5	0.1	5648	98.5
YP	87	1.5	5735	100.0

[1] Refer to Appendix Table D-1 for a list of fish species represented by each code.

Appendix Table C-6. Frequency of fish species caught by anglers while targeting species other than northern squawfish.

Species codes[1]	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AMS	250	6.9	250	6.9
BG	8	0.2	258	7.2
BH	6	0.2	264	7.3
C	210	5.8	474	13.2
CC	309	8.6	783	21.7
CK	1	0.0	784	21.8
CMO	1	0.0	785	21.8
COT	20	0.6	805	22.3
CP	23	0.6	828	23.0
CR	1	0.0	829	23.0
LCH	2	0.1	831	23.1
LMB	18	0.5	849	23.6
LW	2	0.1	851	23.6
NSF	473	13.1	1324	36.7
PMO	193	5.4	1517	42.1
RU	19	0.5	1536	42.6
SA	6	0.2	1542	42.8
SF	1	0.0	1543	42.8
SK	113	3.1	1656	46.0
SMB	1268	35.2	2924	81.2
SP	2	0.1	2926	81.2
SS	10	0.3	2936	81.5
WAL	21	0.6	2957	82.1
WS	462	12.8	3419	94.9
YBH	40	1.1	3459	96.0
YP	144	4.0	3603	100.0
CMO	1	100.0	3604	100.0

[1] Refer to Appendix Table D-1 for a list of fish species represented by each code.

Appendix Table C-7. Frequency of fish species caught by anglers who would have taken this fishing trip if the sport-reward program did not exist.

Species[1] codes	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AMS	228	2.9	236	3.0
BG	27	0.3	263	3.3
BH	249	3.1	512	6.5
BLB	1	0.0	513	6.5
BT	2	0.0	515	6.5
C	390	4.9	905	11.4
CC	466	5.9	1371	17.3
CCT	10	0.1	1381	17.4
CF	1	0.0	1382	17.5
CK	2	0.0	1384	17.5
CMO	30	0.4	1414	17.9
COT	74	0.9	1488	18.8
CP	79	1.0	1567	19.8
CR	3	0.0	1570	19.8
CT	1	0.0	1571	19.8
LCH	81	1.0	1652	20.9
LMB	27	0.3	1679	21.2
LW	2	0.0	1681	21.2
NSF	1897	24.0	3578	45.2
PMO	701	8.9	4279	54.1
RS	50	0.6	4329	54.7
RU	57	0.7	4386	55.4
S	5	0.1	4391	55.5
SA	17	0.2	4408	55.7
SF	28	0.4	4436	56.0
SH	6	0.1	4442	56.1
SK	424	5.4	4866	61.5
SMB	2034	25.7	6900	87.2
SP	6	0.1	6906	87.3
SS	15	0.2	6921	87.4
WAL	40	0.5	6961	87.9
WF	1	0.0	6962	88.0
WS	691	8.7	7653	96.7
YBH	44	0.6	7697	97.2
YP	218	2.8	7915	100.0

[1] Refer to Appendix Table D-l for a list of fish species represented by each code.

Appendix Table C-8. Frequency of fish species caught by anglers who would not have taken this fishing trip if the sport reward program did not exist.

Species[1] codes	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AMS	45	3.2	45	3.2
BH	74	5.2	119	8.4
C	5	0.4	124	8.8
CC	30	2.1	154	10.9
CMO	24	1.7	178	12.6
COT	38	2.7	216	15.2
CP	15	1.1	231	16.3
CR	1	0.1	232	16.4
LCH	10	0.7	242	17.1
LMB	1	0.1	243	17.1
LW	1	0.1	244	17.2
NSF	545	38.5	789	55.7
PGW	6	0.4	795	56.1
PMO	152	10.7	947	66.8
RU	8	0.6	955	67.4
SA	4	0.3	959	67.7
SF	7	0.5	966	68.2
SK	123	8.7	1089	76.9
SMB	208	14.7	1297	91.5
SP	3	0.2	1300	91.7
SS	6	0.4	1306	92.2
TR	3	0.2	1309	92.4
WAL	13	0.9	1322	93.3
WS	81	5.7	1403	99.0
YBH	1	0.1	1404	99.1
YP	13	0.9	1417	100.0

[1] Refer to Appendix Table D-1 for a list of fish species represented by each code.

Appendix Table C-9. Comparison of proportional catch estimates obtained from phone survey data and exit interview data for various fish species caught by non-returning sport-reward program anglers.

Registration	Squawfish under 11"[1]		Smallmouth Bass		White Sturgeon		Summer Steelhead		Walleye		Chinook Salmon	
Station	PHN.[2]	RTN.[3]	PHN.	RTN.	PHN.	RTN.	PHN.	RTN.	PHN.	RTN.	PHN.	RTN.
CATHLAMET	817	538	57	0	11	1	11	3	0	0	0	0
RAINIER	1153	716	0	0	0	1	0	3	0	0	0	0
KALAMA	1721	1306	67	0	0	0	22	10	0	0	0	0
GLEASON	1052	1200	302	16	34	1	0	0	22	25	0	0
CAMAS	398	623	210	91	11	0	0	4	66	11	0	3
FISHERY	972	1180	177	5	0	0	33	1	88	10	11	0
HAMILTON	430	409	111	19	0	1	0	0	0	3	0	0
CAS. L.	761	247	182	47	23	6	23	0	0	4	0	0
BINGEN	1298	336	147	8	34	0	0	1	0	0	0	0
DALLES	1136	589	522	26	23	0	0	0	151	5	0	0
LEPAGE	139	121	329	13	0	1	0	0	25	14	0	0
UMATILLA	142	255	44	52	0	0	0	0	11	70	0	0
COL. P.	144	707	155	71	0	0	0	2	0	0	0	2
VERNITA	1296	161	0	5	0	1	0	1	34	9	0	1
HOOD P.	492	346	425	13	0	0	0	0	0	4	0	0
LYONS F.	358	193	143	38	0	0	0	0	0	0	0	0
BOYER P.	66	149	330	25	0	0	0	0	0	0	0	0
GREENBELT	423	615	958	251	0	0	0	3	0	0	0	0
TOTAL	12825	10171	4146	644	136	14	91	26	397	158	11	6

[1] The phone survey estimates of the number of each species removed does not include fish that were returned to the water unharmed.
[2] Phone survey proportional estimates (the number of fish removed by phone survey anglers/the number of phone survey anglers) x the total number of non-returning anglers.
[3] Returning anglers proportional estimates (the number of fish removed by returning anglers/the number of returning anglers) x the total number of non-returning anglers.

Table 10. Total catch estimates of northern squawfish under 11 inches by non-returning anglers, along with confidence intervals and the percent of the catch returned to the water unharmed.

REGISTATION STATIONS	NON RETURN TOTAL	NON RETURN SAMPLE	NUM.NSF CAUGHT UNDER11	EST. NSF CAUGHT UNDER11	UNDER11 VARIANCE	UNDER11 CONFIDENCE INTERVAL	NUM.NSF RETURNE UNDER11	% of NSF RETURNED UNHARMED
CATHLAMET	862	76	117	1327	12.82	676	45	0.38
RANIER	678	60	159	1797	21.64	777	57	0.36
KALAMA	1299	117	271	3009	58.2	1748	116	0.43
GLEASON	1354	121	222	2484	48.21	1631	128	0.58
CAMAS	1524	138	109	1204	4.08	500	73	0.67
FISHERY	1116	101	99	1094	14.52	807	11	0.11
HAMILTON	1216	99	57	700	3.69	450	22	0.39
CASCADE L.	693	61	185	2102	83.24	1546	118	0.64
BINGEN	779	69	158	1784	116.82	1935	43	0.27
DALLES	881	76	122	1414	20.66	878	24	0.20
LEPAGE	923	73	97	1226	69.36	1727	86	0.89
UMATILLA	789	72	44	482	4.41	372	31	0.70
COLUMBIA P.	942	85	19	211	1.56	243	6	0.32
VERNITA	1127	100	172	1938	35.25	1277	57	0.33
HOOD P.	1488	133	77	861	8.76	729	33	0.43
LYONS F.	775	65	110	1312	28.09	975	80	0.73
BOYER P.	716	65	24	264	16.27	683	18	0.75
GREENBELT	2596	233	141	1571	6.31	815	103	0.73
TOTAL	19758	1744	2183	24731	27.77	4761	1051	0.48

Table 11. Total catch estimates of northern squawfish over 11 inches by non-returning anglers, along with confidence intervals and the percent of the catch returned to the water unharmed.

REGISTRATION STATIONS	NON RETURN TOTAL	NON RETURN SAMPLE	NUM.NSF CAUGHT OVER 11"	EST. NSF CAUGHT OVER 11"	OVER 11" VARIANCE	OVER 11" CONFIDENCE INTERVAL	NUM.NSF RETURNE OVER11	% of NSF RETURNED UNHARMED
CATHLAMET	862	78	1	11	0.03	33	1	1.00
RANIER	678	60	16	181	11.81	574	15	0.94
KALAMA	1299	117	6	67	0.48	159	0	0.00
GLEASON	1354	121	13	145	1.02	237	0	0.00
CAMAS	1524	138	27	298	2.21	368	20	0.74
FISHERY	1116	101	20	221	3.31	385	0	0.00
HAMILTON	1216	99	9	111	0.65	189	2	0.22
CASCADE L.	693	61	2	23	0.18	72	0	0.00
BINGEN	779	69	1	11	0.05	40	0	0.00
DALLES	881	78	7	81	0.61	151	2	0.29
LEPAGE	923	73	31	392	8	586	3	0.10
UMATILLA	789	72	8	88	0.94	172	0	0.00
COLUMBIA P.	942	85	25	277	1.55	243	0	0.00
VERNITA	1127	100	31	349	2.4	333	0	0.00
HOOD P.	1488	133	23	257	1.19	269	1	0.04
LYONS F.	775	65	9	107	0.53	134	0	0.00
BOYER P.	716	65	0	0	0	0	0	0.00
GREENBELT	2596	233	33	368	1.06	334	5	0.15
TOTAL	19758	1744	262	2968	1.83	1222	49	0.19

Recall Bias Survey Results

No statistically significant differences ($P > 0.222$) were found in the anglers' ability to recall the catch of northern squawfish over 11 inches among any of the week intervals (Appendix E). Anglers did not recall the number of northern squawfish over 11 inches caught at two weeks from the fishing trip more accurately than anglers surveyed at 12 weeks from the fishing trip. Anglers who classified their memory of a particular fishing trip as "very well" did not remember the catch of northern squawfish over 11 inches more accurately than anglers who classified their memory of a particular fishing trip as "not well" ($P > 0.721$). No statistically significant differences ($P > 0.936$) were found among anglers when comparing weeks and memory levels for northern squawfish over 11 inches.

Anglers who caught northern squawfish under 11 inches showed no statistically significant differences among weeks ($P > 0.823$), memory ($P > 0.287$), or week and memory ($P > 0.253$).

Discussion

Phone Survey Discussion

Future sport-reward fishery promotional efforts should emphasize the value of the program in protecting salmon populations, since 95% of surveyed anglers participated to help salmon (Appendix Table C-4). Oregon Department of Fish and Wildlife estimates regarding the percent reduction in juvenile salmonid losses due to predation should be publicized to anglers. Participation in the sport-reward fishery could increase if anglers were shown how their efforts increased salmon survival. A majority (77%) of non-returning anglers participated in the fishery because of the reward. Promotional programs, such as derbies, reward tags, and drawings could offer additional incentive for anglers to participate in the program.

Angler satisfaction with registration station locations was high (84%), but should be monitored as registration station locations change to ensure that participation in the sport-reward fishery does not drop due to low angler satisfaction with the registration locations. The current procedures for hiring and training technicians met the expectations of the sport-reward fishery anglers, since 99% of surveyed anglers rated interaction with the registration station technicians to be either "very good" or "good."

Anglers can accept occasionally not catching reward-size northern squawfish and still continue participating in the fishery. Non-returning anglers did not catch enough northern squawfish to make it worthwhile returning to the check station for a pay voucher and an exit interview, but 94% of the non-returning anglers were sufficiently satisfied with the fishery to continue future participation.

Anglers who target fishes other than northern squawfish register with the sport-reward fishery to collect the $3 reward on northern squawfish caught incidentally. Other anglers register with the sport-reward fishery specifically to target northern squawfish and to receive the reward. The majority of sport-reward anglers (61%) caught fish while targeting northern squawfish; anglers who target northern squawfish caught approximately 20% more northern squawfish than anglers who targeted other fishes, which shows sport-reward fishery anglers were more likely to exploit northern squawfish than other fishes.

Approximately 77% of anglers surveyed would have taken the fishing trip even if the sport-reward program did not exist and they caught 82% of all fish caught by non-returning anglers, which shows that many of the fish caught by non-returning anglers would have been caught regardless of the sport-reward fishery's existence. The majority of non-returning anglers simply wanted to go fishing and the sport-reward fishery offered the opportunity plus a reward. The sport-reward fishery may have reduced fishing pressure on other game fish species, since anglers would most likely target species other than northern squawfish in the absence of a reward. Appendix Table C-9 also shows the number of popular game and food fish caught incidentally by non-returning anglers was low and had little impact on the population size of any fish species other than northern squawfish. The fact that non-returning anglers returned 65% of all fish caught to the water unharmed also lowered the sport-reward fisheries effect on Columbia and Snake river fishes.

Since phone survey estimates of the number of fish removed by non-returning anglers were higher than returning anglers' estimates for all fishes compared (Appendix Table C-9), no further statistical analysis was necessary to justify the continuation of the phone survey estimates in 1994. The preservation of sensitive populations of fishes requires us to favor liberal catch estimates. Estimates of the number and type of fish caught by non-returning anglers could be made from returning angler data if returning anglers were shown to catch the same number and type of fishes as non-returning anglers and allowed all fish caught to be recorded in the exit interview. Some returning anglers were unwilling to take the time to show their catch to technicians. Under the 1993 rules, a technician could not record an angler's catch if the angler was unwilling to show their catch. Low returning angler estimates for 1993 data were due to incomplete catch data. The 1994 returning angler estimates for game and food fish will be improved by not requiring anglers to show the day's catch to technicians and by the addition of voucher questions that require returning anglers to record catch information. Comparisons will be made of the 1994 phone survey catch estimates, returning angler catch estimates, and voucher catch estimates to verify the findings of the 1993 phone survey. Returning angler estimates of northern squawfish removed under 11 inches were the closest to the phone survey estimates because returning anglers commonly turn in all northern squawfish caught.

The percentage of northern squawfish under 11 inches returned to the water unharmed varied among check stations from 11% to 75% (Appendix Table C-10). Returning fish to the water unharmed reduced our removal estimate of the number of northern squawfish under 11 inches from 24,731 (Appendix Table C-10) to 12,825 (Appendix Table C-9). Non-returning anglers are harvesting insignificant numbers of northern squawfish under 11 inches, which is consistent with the goals of the sport-reward fishery.

The estimated number of northern squawfish over 11 inches caught by non-returning anglers (2,968) was low, since most anglers want to receive the $3 reward. An unexpected finding was that 37% of northern squawfish over 11 inches caught by non-returning anglers were returned to the registration station. The phone survey question addressing how anglers disposed of the fish was not designed to determine why a non-returning angler would profess to be a returning angler. Surveyed anglers may have confused a day when they did not return to the registration station with a day they did return. Some anglers could have considered that giving northern squawfish to another angler to return to the registration station was the same as returning the fish themselves. The 1994 phone survey will be designed to find out exactly what non-returning anglers mean when they profess to have returned the day's catch to the registration station. Less than 1% (0.38 %) of the northern squawfish over 11 inches were kept to eat by anglers, indicating that northern squawfish are not a popular food fish. Anglers who caught only one or two northern squawfish over 11 inches may find it impractical to drive back to the registration station for such a small reward. Rather than waste a fish worth $3, non-returning anglers gave 21% of the catch of northern squawfish over 11 inches to other anglers. Approximately 19% of the northern squawfish over 11 inches caught by non-returning anglers were returned to the water unharmed, perhaps by anglers hoping to catch the fish on a more productive day.

Recall Bias Study Discussion

The recall of non-returning anglers was assumed to be equal to the recall of returning anglers so that inferences could be made about the accuracy of the phone survey data (non-returning anglers) from the results of the recall bias study (returning anglers). No significant difference was found in anglers' recall of the number of northern squawfish caught over 11 inches ($P < .222$) or under 11 inches ($P < .824$) at 2-, 4-, 6-, 8-, 10- or 12-week periods. The recall bias study showed that even though an individual angler's response may be incorrect, when all of the anglers' data were analyzed, catch data from anglers surveyed at two weeks from the fishing tip was not significantly ($P > 0.05$) less accurate than catch data gathered at 12 weeks.

Anglers evaluated memory of a particular fishing day as either "very good," "good" or "not good" (Appendix Table C-3). No significant difference was found among the three levels of memory for northern squawfish over 11 inches ($P < .721$) or under 11 inches ($P < .287$), which shows that an angler's evaluation of the accuracy of their memory was not the same as the true accuracy of the angler's memory.

The overall accuracy of the phone survey results was not found to be significantly changed by anglers' ability to recall the correct number of fish caught on a fishing trip.

Acknowledgments

The editing provided by Dr. David Bennett substantially improved this paper. Dr. John Tamai, Associate Director of the Social and Economic Sciences Research Center (SESRC) at Washington State University reviewed our questionnaire and advised us on general procedures for conducting a telephone survey. Dr. Dale Everson, Professor of Statistics at the University of Idaho, advised us on the statistical methods used in the survey. Dennis Gillilnd programmed the dBase data files for the study. Daylene Cahill and Diane DuCommun telephoned all survey participants and entered the data. We appreciate the efforts of all those who contributed to the completion of this paper.

APPENDIX D

Fiih Species Codes

Appendix Table D-l. Sport-reward fishery field species codes.

LMB	Bass, Largemouth
RKB	Bass, Rock
SMB	Bass, Smallmouth
SB	Bass, Striped
BG	Bluegill
BH	Bullhead (General)
YBH	Bullhead, Yellow
BBH	Bullhead, Brown
BLB	Bullhead, Black
CP	Carp
BCF	Catfish, Blue
CC	Catfish, Channel
FCF	Catfish, Flathead
AC	Char, Atlantic
C	Crappie (General)
BC	Crappie, Black
WC	Crappie, White
EUL	Eulachon
SF	Flounder, Starry
AG	Grayling, Arctic
TMK	Musky, Tiger
SP	Perch, Shiner
YP	Perch, Yellow
NP	Pike, Northern
PS	Pumpkinseed
AT	Salmon, Atlantic
CK	Salmon, Chinook
CH	Salmon, Chum
CO	Salmon, Coho
K	Salmon, Kokanee
SA	Salmon, Pacific Unknown
PK	Salmon, Pink
SO	Salmon, Sockeye
AMS	American Shad
LFS	Smelt, Longfin
SS	Steelhead, Summer-Run
SW	Steelhead, Winter-Run
SH	Steelhead, Unknown Race
GRS	Sturgeon, Green
WS	Sturgeon, White
S	Sunfish (General)
GS	Sunfish, Green
BT	Trout, Brown
CT	Trout, Cutthroat General
CCT	Trout, Cutthroat Coastal
SCT	Trout, Cutthroat, Coastal
LCT	Trout, Cutthroat Lahontan
WCT	Trout, Cutthroat West
DB	Trout, Dolly Varden/Bull
BLC	Trout, Bull Trout (Char)
DVC	Trout, Dolly Varden (Char)
EB	Trout, Eastern Brook
GT	Trout, Golden
LT	Trout, Lake
RB	Trout, Rainbow Resident
RU	Trout, Rainbow Unknown
TR	Trout, Unknown
WAL	Walleye
WM	Warmouth
LW	Whitefish, Lake
WF	Whitefish, Mountain

NONGAME FISH SPECIES

BUR	Burbot
CMO	Chiselmouth
LCH	Chub, Lake
TCH	Chub, Tui
[1]CRC	Columbia River Chub
LED	Dace, Leopard
LND	Dace, Longnose
SD	Dace, Speckled
GF	Goldfish
LM	Lamprey (General)
PL	Lamprey, Pacific
RL	Lamprey, River
WL	Lamprey, Western Brook
MQF	Mosquitofish
OMM	Mudminnow, Olympic
PMO	Peamouth
P	Pickerel, Grass
SAN	Sandroller
COT	Sculpin (General)
CSS	Sculpin, Coastrange
MRS	Sculpin, Margined
MTS	Sculpin, Mottled
PSS	Sculpin, Pacific
PTS	Sculpin, Piute
PRS	Sculpin, Prickly
RTS	Sculpin, Reticulate
RFS	Sculpin, Riffle
SHS	Sculpin, Shorthead
SLS	Sculpin, Slimy
TRS	Sculpin, Torrent
RS	Shiner, Redside
NSF	Squawfish, Northern
TSS	Stickleback,Three-Spine
SK	Sucker (General)
BRS	Sucker, Bridgelip
RS	Sucker, Largescale
LNS	Sucker, Longnose
MNS	Sucker, Mountain
TMT	Tadpole Madtom
TNC	Tench
WAD	White Amur-diploid
WAT	White Amur-triploid
PGW	Whitefish, Pygmy

[1] Conventional naming for NSF sport-reward program.

APPENDIX E

Recall Bias Study ANOVA Results

Appendix Table E-l. General linear model results for the difference between exit interview and recall bias study answers for northern squawfish over 11 inches in total length.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
WEEK	6	2 4 6 8 10 12
MEMORY	3	1 2 3

Number of observations in data set = 414

General Linear Models Procedure

Dependent Variable: DIFFl

Source	DF	Sum of Sauares	Mean Sauare	F Value	Pr > F[1]
Model	17	744.726	43.807	0.70	0.8032
Error	396	24775.401	62.564		
Total	413	25520.128			

R-Sauare	C.V.	Root MSE	DIFF1 Mean[2]
0.029182	-4485.803	7.90975	-0.17633

Source	DF	Type I SS	Mean Sauare	F Value	Pr > F
WEEK	5	439.388	87.877	1.40	0.2216
MEMORY	2	40.928	20.464	0.33	0.7212
WEEK*MEMORY	10	264.410	26.441	0.42	0.9356

Source	DF	Type III SS	Mean Sauare	F Value	Pr > F
WEEK	5	504.353	100.870	1.61	0.1557
MEMORY	2	51.539	25.769	0.41	0.6627
WEEK*MEMORY	10	264.410	26.441	0.42	0.9356

[1] Probability of making a type one error.

[2] Average value of the difference between exit interview responses and recall bias study responses to the question: "How many northern squawfish did you catch over 11 inches in total length."

Appendix Table E-2. General linear model results for the difference between exit interview and recall bias study answers for northern squawfish under 11 inches in total length.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
WEEK	6	2 4 6 8 10 12
MEMORY	3	1 2 3

Number of observations in data set = 437

General Linear Models Procedure

Dependent Variable: DIFFl

Source	DF	Sum of Squares	Mean Sauare	F Value	Pr > F[1]
Model	17	112.912	6.641	1.01	0.4408
Error	419	2743.224	6.547		
Total	436	2856.137			

R-Sauare	C.V.	Root MSE	DIFF1 Mean[2]
0.039	-947.595	2.55873	-0.27002

Source	DF	Type I SS	Mean Sauare	F Value	Pr > F
WEEK	5	14.270	2.854	0.44	0.8235
MEMORY	2	16.412	8.206	1.25	0.2866
WEEK*MEMORY	10	82.229	8.222	1.26	0.2534

Source	DF	Type III SS	Mean Suuare	F Value	Pr > F
WEEK	5	17.708	3,541	0.54	0.7452
MEMORY	2	14.257	7.128	1.09	0.3376
WEEK*MEMORY	10	82.229	8.222	1.26	0.2534

[1] Probability of making a type one error.

[2] Average value of the difference between exit interview responses and recall bias study responses to the question: "How many northern squawfish did you catch under 11 inches in total length."

APPENDIX F

Computerized Data Collection Analysis

Computerized Data Collection Methods

A computerized data collection station was tested at the Hamilton Island registration site. This water-resistant work station incorporated an electronic balance, metric length measurement scale, a digitizer, multiplexer, an external computer keyboard, a laptop computer, and a 12-volt DC power source. A customized software package developed by the work station manufacturer, Biomark Inc[1]., enabled Washington Department of Fish and Wildlife (WDFW) technicians to enter registration, exit interview, and biological data directly onto a computer diskette. This data was audited by the software upon entry, alerting the technicians to errors or omissions in the data while the registrant and specimens were still on hand. At the end of the evening shift, WDFW technicians would remove the labeled computer diskette that included all data from both shifts.

The time required to record data was measured for each of three technicians using the computerized data recording system and the manual data recording system. The study was conducted for two test periods, each consisting of one week of manual data and one week of computer data. The tests were conducted using actual anglers registering and exiting from the northern squawfish sport-reward fishery. Each technician was randomly assigned to either computer method or manual method at the beginning of each two-week test period. Test data from set variables and times were recorded onto weekly data forms and entered into a data base. All three technicians had prior experience recording data manually, but no experience entering data using the computerized method.

Four types of tests were conducted. Each test recorded the amount of time required by a technician to enter a registration form, conduct an exit interview, and to record biological data for 10 northern squawfish and 30 northern squawfish. Biological data consisted of recording the species of fish and measuring the fork length and weight of the fish. Time was measured by a stop watch. Technicians were tested five times per week on the manual and computerized method for comparing registration time. Exit interviews were tested 10 times per week using both manual and computer methods. Biological data recording time was tested five times per week using 10 and 30 northern squawfish for each test.

One person tested all technicians for both test periods. Registration and exit interview data on the manual system was measured by timing from when the pen first marked the form until the pen left the paper on the last data record. Computerized data collection for

[1] Mention of a manufacturer by the Washington Department of Fish and Wildlife does not constitute endorsement.

registration and exit interview data was timed from when the first key was struck to begin data entry until the last key was struck completing data entry. Biological data timing for the manual method began when the first northern squawfish was placed on the measuring board and ended when the last fish was completed. Biological data timing for the computerized method began when the first northern squawfish was placed on the digitizing pad and ended when the last fish was completed.

A paired t-test was used to test for significant differences between treatment groups (alpha=0.05). The sum of the differences between the paired tests was computed. A negative sum indicated the manual system was faster than the computer system and a positive sum indicated the computer system was faster than the manual system.

Computerized Data Collection Station Results

Registration Interview Comparison

The overall results of the six paired registration tests showed no difference between the speed of manual data entry and computer data entry (Appendix Table F-l). However, the general linear model showed the second period to be significantly faster than the first period. No significant difference existed among the three technicians for processing registration information.

Exit Interview Comparison

The overall results of the six paired exit interview tests indicated the computer method was significantly faster than the manual method (Appendix Table F-l). The general linear model showed a significant difference among the technicians. No significant difference was found between periods.

Biological Data Collection Comparison

The overall results of the six paired, 10-fish biological tests indicated the computer method was significantly faster than the manual method (Appendix Table F-l). The general linear model showed a significant difference among the technicians. Significant differences were found between periods. The mean time for a lo-fish biological test on the computer (3.8 minutes) was approximately twice as fast as the manual method mean time (7.27 minutes).

The overall results of the six paired 30-fish biological data tests indicated the computer method was significantly faster than the manual method. The general linear model showed a significant difference among the technicians. Significance was not found between periods. The mean time for a 30-fish biological data test on the computer (10.87 minutes) was approximately twice as fast as the manual method mean time (20.41 minutes). These results matched the results of the lo-fish biological data test.

Appendix Table F-l. Test results of the computerized data collection unit verses manual data collection.

PROC UNIVARIATE RESULTS[1]	GENERAL LINEAR[2] MODEL RESULTS		
REGISTRATION TEST COMPARISON			
N[3] = 30	DIFF MEAN[4]	-0.20	
SUM[5] = -6.1	MODEL	P<0.008	S[6]
P< 0.0842 NS[7]	TECHNICIAN	P<0.067	NS
	PERIOD	P<0.001	s
EXIT INTERVIER TEST COMPARISON			
N = 60	DIFF MEAN	0.593	
SUM = 35.6	MODEL	P<0.001	s
P<0.0001 s	TECHNICIAN	P<0.001	s
	PERIOD	P<0.817	NS
10 BIOLOGICAL TEST COMPARISON			
N = 30	DIFF MEAN	3.47	
SUM = 104.1	MODEL	P<0.002	s
P<0.0001 s	TECHNICIAN	P<0.013	s
	PERIOD	P<0.002	s
30 BIOLOGICAL TEST COMPARISON			
N = 30	DIFF MEAN	9.54	
SUM = 286.2	MODEL	P<0.001	s
P<0.0001 s	TECHNICIAN	P<0.001	s
	PERIOD	PC0.845	NS

[1] SAS procedure for performing a paired T-Test.
[2] SAS procedure for performing general linear models.
[3] Total number of tests conducted.
[4] Mean value of the difference between each pair of tests (a positive value indicated a faster data entry time for the computer method and a negative value indicates a faster time for the manual method).
[5] Sum of the differences between each pair of tests.
[6] Significant at an alpha level of 0.05.
[7] Not significant at an alpha level of 0.05.

Error Rates

The error rate results (Appendix Table F-2) showed a significant reduction in the number and percent of errors entered by each technician between Period 1 and Period 2 for registration and exit, and biological data entry. The percentage of errors was also higher with technicians that entered data faster as indicated by a higher number of total fields entered.

Computerized Data Collection Station vs Manual Discussion

The general linear model results (Appendix Table F-l) did show the second period was significantly faster than the first period for the registration test comparison, indicating that more experience on the computerized system was necessary for the computerized system to be more efficient than the manual. The registration test was the only test type that did not show a significant difference between the computer and manual systems. More fields are typed into the computer system for a registration test than any of the other test types, perhaps requiring more time for technicians to become proficient. No significant difference existed among the three technicians for a registration test indicating similar levels of efficiency among the technicians.

The general linear model results (Appendix Table F-l) also showed a significant difference among the technicians for the exit interview comparison, indicating that some technicians were faster than others with exit tests. No significance was found between periods, showing no significant improvement with experience in exit interviews. Anglers liked to talk with the technicians after a fishing trip, which sometimes caused delays in the exit interview and added a source of variance. This variance from fishermen conversation could mask any actual gains in speed of the technicians between periods.

The mean time for a 10-fish biological test on the computer (3.8 minutes) was approximately twice as fast as the manual method mean time (7.27 minutes). This indicates that biological data could be entered about twice as fast using the computer method as the manual method. Significance was also found between periods, showing improvement with experience.

The overall results of the six paired, 30-fish biological data tests indicate the computer method is significantly faster than the manual method. The general linear model showed a significant difference among the technicians indicating that some technicians were faster than others. Significance was not found between periods, showing no improvement with experience.

Appendix Table F-2. Technician error rates using the Biomark computerized data collection unit.

REGISTRATION AND EXIT DATA ERROR RATES

	TECHNICIAN		
	A	B	C
PERIOD 1			
TOTAL FIELDS	957	2900	32191
TOTAL ERRORS	71	277	2411
ERROR PERCENT	7.42	9.55	7.49
	A	B	C
PERIOD 2			
TOTAL FIELDS	667	2088	18272
TOTAL ERRORS	11	41	492
ERROR PERCENT	1.65	1.96	2.68

BIOLOGICAL DATA ERROR RATES

	A	B	C
PERIOD 1			
TOTAL FIELDS	810	4014	1539
TOTAL ERRORS	38	236	291
ERROR PERCENT	4.69	5.88	1.88
	A	B	C
PERIOD 2			
TOTAL FIELDS	135	1062	14762
TOTAL ERRORS	0	2	42
ERROR PERCENT	0.00	0.19	0.27

The results of the 10- and 30-fish biological data comparisons indicate that biological data could be entered about twice as fast using the computer method as the manual method.

Appendix Table F-2 illustrates that technicians make a high number of mistakes initially on the computerized system, but adjust quickly to the system and error rates drop with more experience.

The computer method has the advantage of recalling an angler's registration data after an initial entry. An angler who is participating in the program more than once would already have most of the registration data already entered into the computer. In practice, a higher percentage of anglers will have registration data previously entered as the season progresses resulting in the computer system increasing in efficiency. The computerized data unit could be improved by allowing data to be downloaded from the computer using a serial communications program.

The computerized data collection method allows data to be loaded directly into the data base. The manual data method must go one step further requiring additional staff to enter these data. The Hamilton Island registration station had data entry personnel manually enter 2,625 registration documents in 250 hours (technician wage = $9.40/hr.). If the computerized data collection unit was used for the entire season (assuming all computer problems could be solved), a $2,335 savings in data entry costs would have been realized. Cost savings from a computerized data collection unit can only be achieved at registration stations that process large amounts of data. With the collection of biological data not being a contract objective by WDFW, we feel that the computerized data collection unit should not be used for the 1994 sport-reward fishery. We will continue to collect biological data as time allows and provide it to the Oregon Department of Fish and Wildlife.

REPORT C

Northern Squawfish Sport-Reward Payments

Prepared by

Russell G. Porter

Pacific States Marine Fisheries Commission
45 S.E. 82nd Drive, Suite 100
Gladstone, Oregon 97027

1993 Annual Report

CONTENTS

INTRODUCTION

The Pacific States Marine Fisheries Commission (PSMFC) provided fiscal services for payment of the squawfish sport rewards. Anglers registered and subsequently checked in their catch at the Washington Department of Fish and Wildlife field stations where they received a voucher for all eligible fish checked in. The vouchers were then sent by the angler to the sport-reward post office box in Oregon City. Vouchers were received and paid during the fishery from May through September. A cut-off date of October 15, 1993, was established as the final date vouchers needed to be postmarked to receive payment from PSMFC. These dates were printed in bold on the vouchers. PSMFC allowed one month past the official cut-off date for receipt of the vouchers, then started rejecting late vouchers because of logistics and the need for IRS reporting for the calendar year. The following sections summarize the vouchers paid this year.

VOUCHER PAYMENTS

A total of 12,351 vouchers were received for payment in the 1993 fishing season. They represented 101,697 fish for a total possible reward payment of $305,09 1. Of this total, 141 vouchers for 398 fish ($1,194) remain unpaid. Therefore, the total rewards actually paid were for $303,897, representing 101,299 fish on 12,210 vouchers. Rejected vouchers are addressed in a later section of this report. Table C-l summarizes the vouchers received for payment (including rejects) by month and their potential reward payments.

The voucher files can also be used to readily summarize the date fish were caught by month. This is a more useful statistic for review of the fishery than the payment date of vouchers. Rejected vouchers are included in this summary of month of catch. Some of these rejects had dates associated with them and some did not. Those for which a date is known are included in the appropriate month. Those rejects for which no date is in the system are listed at the bottom of the table. Table C-2 provides information about the month in which fish were caught whether a reward was paid or not.

Voucher processing proceeded smoothly. Depending on volume received, checks were cut and mailed to the angler within l-5 days after receipt of the voucher. Those vouchers that had missing or incomplete information were returned to the angler for completion. A total of 646 vouchers were rejected upon initial receipt for one reason or another. At the end of the season, 141 vouchers remain in the reject file worth $1,194, making the total rewards paid $303,897 for 101,299 fish on 12,210 valid vouchers.

Table C-l. Vouchers received for payment by month and their potential reward payments.

Month received	Vouchers	Number fish	Potential reward payment
May	868	5,705	$ 17,115
Jun	3,612	34,107	$ 102,321
Jul	3,033	29,664	$ 88,992
Aug	2,220	16,401	$ 49,203
Sep	2,081	13,680	$ 41,040
Oct	468	1,946	$ 5,838
Nov	48	145	$ 435
Dec[1]	12	29	$ 87
Jan’	6	10	$ 30
Feb[1]	3	10	$ 30
TOTALS:	12,351	101,697	$305,091

[1] Vouchers paid these months were initially received by the deadline, but subsequently returned to the angler one or more times for missing information.

Table C-2. Month, number of vouchers, and number of fish caught in the 1993 sport-reward fishery.

Month caught	Vouchers	Number fish	Av. fish/ voucher	Potential reward payment
May	2,511	16,429	6.5	$ 49,287
Jun	4,176	39,009	9.3	$117,027
Jul	2,973	27,594	9.3	$ 82,782
Aug	1,940	13,116	6.8	$ 39,348
Sep	637	5,232	8.2	$ 15,696
Rejects: (Date Unavail.)	114	317		$ 951
TOTALS	12,351	101,697		$305,091

REJECTED VOUCHERS/MISCELLANEOUS PAYMENTS

A total of 646 vouchers were rejected for various reasons either upon initial receipt or later when checks were returned by the post office as undeliverable. As the season progressed, 505 of these eventually cleared and were paid. There remain 141 vouchers that cannot be paid for various reasons such as having been sent back to the angler for missing data and not returned to PSMFC, bad addresses, etc. Tables C-3 and C-4 summarize initial reject categories and those 141 vouchers that did not clear.

We received a couple garnishments for anglers from the IRS and the State of Washington Support Enforcement Division. We honored and paid to the two agencies the amount requested from the appropriate angler's reward payments. Legal opinion sought by PSMFC from our state of Oregon assigned assistant attorney general from the Justice Department validated our need to pay the State of Washington Support Enforcement garnishment.

Table C-3. Summary of vouchers initially rejected upon receipt - 646 total.

	Number of vouchers
Returned To WDW for Missing Data:	
Missing # fish Caught	1
Missing Creel Clerk Signature	4
Date Not Filled In	1
No Signatures	1
Missing Signature & Trip Data	1
Missing Site Code	1
Returned to Angler for Missing Data:	
No Angler Signature	5
Missing Social Security #	1
Missing Signature & Social Security #	1
Questionnaire Not Completed	370
Angler Data Missing	170
Questionnaire & Angler Data Missing	10
Bad Address (Check Voided)	27
Past Deadline for Payment	45
TOTAL:	646

Table C-4. Summary of final voucher rejects at end of season - 141 total.

	Number of vouchers
Questionnaire Not Completed[1]	47
Angler Data Missing[1]	19
Questionnaire & Angler Data Missing[1]	**3**
Bad Address (Check Voided)	27
Past Deadline For Payment	45
TOTAL:	141

[1] Returned to Angler & not returned to PSMFC with missing data completed.

FISCAL STATEMENTS/REPORTS

All IRS Form 1099-Misc. statements were sent to the qualifying anglers for tax purposes the third week in January. Appropriate reports and copies were provided to the IRS by the end of February.

MISCELLANEOUS WORK

In the last quarter of the current contract period, work centered on cleaning up the voucher data entry program and associated accounting cross-checks, reports and voucher tracking and editing routines. The program has become more sophisticated to allow most all options necessary by means of program menus without the need for special programming expense or computer program technician time. We now have the option to look at previous years' data and to carry forward certain files and angler data to shorten data entry time. We have also added the ability to carry forward suspense vouchers and those rejected or on hold, should they clear in the future for payment. Recent additions also allow for the carry forward of IRS or other agency garnishments that extend across two or more fishing periods (years).

REPORT D

Controlled Angling for Northern Squawfish at Selected Dams on the Columbia and Snake Rivers and Diet Analysis of Incidentally Caught Channel Catfish

Prepared by

Columbia River Inter-Tribal Fish Commission
729 N.E. Oregon, Suite 200
Portland, Oregon 97232

1993 Annual Report

CONTENTS

ACKNOWLEDGEMENTS

We thank Silas Whitman and Manuel Villalobos (Nez Perce Tribe); Gary James and Jed Volkman (Confederated Tribes of the Umatilla Indian Reservation); Lynn Hatcher, Steve Parker, and George Lee (Confederated Tribes and Bands of the Yakima Indian Nation); and Jim Griggs, Mark Fritsch, and Henry Palmer (Confederated Tribes of the Warm Springs Reservation of Oregon) for implementing the work performed by subcontractors. Our deep appreciation goes to Columbia River Inter-Tribal Fish Commission and subcontractor technicians who fulfilled their duties admirably throughout the season. We greatly appreciate the contributions of Jack McCormack, Bob Samuels, and Jennifer Oatman for preparing biological samples, keying diagnostic bones, and processing diet analysis data.

Personnel from the U.S. Army Corps of Engineers were invaluable in their cooperation and coordination: Jim Kuskie and Dennis Schwartz (Bonneville Dam); Jim Williams and Bob Dach (The Dalles and John Day dams); Peter Gibson and Brad Eby (McNary Dam); Bill Spurgeon (Ice Harbor and Lower Monumental dams); Rex Baxter and Rebecca Kalamasz (Little Goose Dam); and Jesse Smiley, Tim Wik, Mike Halter, and Ron Robson (Lower Granite Dam).

We extend a special thanks to the volunteer anglers from the Portland and Tom McCall Chapters of Northwest Steelheaders, The Dalles Rod and Gun Club, Mid Columbia Bass Anglers, and the High Desert Chapter of The Ladies Angle Fishing Society.

For the diet analysis, Tom Poe and Conrad Frost (U.S. Fish and Wildlife Service) provided valuable advice and assistance, and Dave Ward and Chris Knutsen (Oregon Department of Fish and Wildlife) provided laboratory space and other help.

Becky Ashe, Roy E. Beaty, Ken Collis, Kathy McRae and Blaine Parker (alphabetical order) contributed to this report.

ABSTRACT

During our third season, 1993, field crews fished from mid-May through early September at eight lower mainstem dams on the Columbia and Snake rivers and had a confirmed catch of 16,949 northern squawfish (*Ptychocheilus oregonensis*). Total effort and northern squawfish catch were 61% and 58%, respectively, of those in 1992. Overall catch per angler hour (CPAH; 1.7) was essentially unchanged. Effort has been reduced most at Snake River dams (by 79% since 1991) because of continuing low CPAH (0.5 in 1993) relative to Columbia River dams (2.0 in 1993). At Columbia River dams, increased catch rates (relative to 1992) at Bonneville (from 2.7 to 2.9) and John Day dams (from 1.2 to 2.2) were offset by larger decreases at The Dalles (from 3.0 to 1.4) and McNary dams (from 2.9 to 1.9).

We continued to shift effort to the most productive dams and to use volunteer anglers and boat angling to improve efficiency. Volunteer anglers from five sporting groups contributed 266 hours of effort and caught 550 northern squawfish, 3.2% of the season total. Although boat angling in the tailraces was generally more effective than concurrent angling on the dams, we cannot conclude that it is more efficient than dam-based angling.

Incidental species composed a slightly lower percentage of the total catch in 1993 (5.5 %) than in 1992 (5.8%), although the contribution by bass (*Micropterus* spp.) roughly doubled (from 1 .O% to 2.1%) and partially offset a decrease ‘in the percentage of catfish (*Ictalurus* spp.; from 3.7% to 2.0%) in our catch. Three juvenile and three adult salmonids (*Oncorhynchus* spp.) were caught, and all except one of the juveniles were released in good condition.

Incidentally caught channel catfish (Z. *punctatus*) sampled at McNary Dam and Snake River dams from June through August contained an average of 0.05 juvenile salmonids (only two, total), one-third of the average (0.16) for northern squawfish sampled from the same dams and months. However, these results have several limitations. A high incidence of fall chinook salmon from Lyons Ferry Hatchery in northern squawfish samples from Lower Monumental Dam suggests a high predation rate on these summer-released fish.

INTRODUCTION

Historically, juvenile salmonids (*Oncorhynchus* spp.) in the Columbia-River and its tributaries encountered few obstacles during their downstream migration to the sea. However, numerous hydroelectric dams have transformed the Columbia and Snake rivers into a series of reservoirs that slow the migration of juvenile salmonids (Raymond 1988). The dams have also created feeding stations for predators, particularly in tailrace areas (Raymond 1988). Northern squawfish (*Ptychocheilus oregonensis*) were identified as the primary predator of juvenile salmonids in the John Day Reservoir during a multi-year study (Poe et al. 1991).

Hook-and-line angling from the dams effectively removes northern squawfish (Vigg et al. 1990; Beaty et al. 1993; Parker et al. 1993) from the areas where predation is most severe (Rieman et al. 1991; Petersen, in review). Through 1992, dam angling removed approximately 78,219 northern squawfish from eight dams on the lower Columbia and Snake rivers (Vigg et al. 1990; Beaty et al. 1993; Parker et al. 1993). In 1993, the Columbia River Inter-Tribal Fish Commission (CRITFC) and its member tribes sought to (1) efficiently remove northern squawfish from areas adjacent to dams; (2) minimize incidental catch of salmonids (*Oncorhynchus* spp.), white sturgeon (*Acipenser transmontanus*), and other species; (3) determine whether incidentally caught channel cattish (*Ictalurus punctatus*) were also preying on juvenile salmonids; and (4) continue developing and implementing more effective and efficient methods (e.g., volunteer and boat angling) for removing northern squawfish near dams.

METHODS

Dam Angling

Angling crews fished at eight U.S. Army Corps of Engineer (Corps) dams on the lower Columbia and Snake rivers in 1993 (Table D-l and Figure D-l). We distributed effort based in part on 1992 results and on inseason CPAH patterns. For example, we delayed starting some crews because of the cool, wet spring. Also, crews sometimes worked split shifts to cover high catch periods at dawn and dusk, and the large crew at McNary Dam divided into two smaller crews during the peak of the season to distribute effort over seven days per week.

The efforts of crews at some dams were augmented by a mobile crew, volunteer anglers, and boat angling (Table D-2). The mobile crew fished the most productive dams on the lower Columbia River and helped supervise volunteer anglers. Members of five sport angling groups volunteered to fish some weekend evenings at Bonneville, The Dalles, and McNary dams during a six-week period in July and August. Boat angling was restricted to the tailrace boat restricted zones (BRZ) during daylight hours. Concurrent angling on the dam, itself, provided the standard for evaluating the effectiveness of boat angling. We did not formally evaluate the performance of the mobile crew and volunteer anglers.

Angling equipment and techniques, including measures to minimize incidental catch, were essentially the same as those used in 1992 (Parker et al. 1993). When dead juvenile salmonids were used for bait, their heads were removed and discarded so that the diagnostic bones (e.g., dentaries and cleithra) would not bias the results of our diet analysis. We continued our “no-touch” policy for all salmonids ≥ 0.50 m (1.5 ft) and sturgeon ≥ 0.75 m (approx. 2.5 ft), which were immediately cut free to avoid unnecessary handling stress and injury. Smaller salmon and sturgeon and other incidental species were reeled in, unhooked, and released. We used debarbed bronzed hooks, which allowed incidental species to be released with less injury and allowed hooks retained by large incidental fish to disintegrate.

Table D-l. Distribution of angling effort at Columbia and Snake River dams in 1993.

Dam (river km)	Season	Supervised by
<u>Columbia River</u>		
Bonneville (233)	May 24-Sept 10	CTWS[a]
The Dalles (310)	May 24-Sept 16	CTWS
John Day (348)	June 7-Sept 16	YIN[b]
McNary (470)	June 2-Sept 2	CTUIR[c]
<u>Snake River</u>		
Ice Harbor (16)	June 21-Aug 31	CTUIR
Lower Monumental (68)	July 12-Aug 30	CTUIR
Little Goose (113)	May 17-Sept 2	NPT[f]
Lower Granite (172)	May 17-Sept 3	NPT

[a] Confederated Tribes of the Warm Springs Reservation of Oregon

[b] Confederated Tribes and Bands of the Yakima Indian Nation

[c] Confederated Tribes of the Umatilla Indian Reservation

[d] Nez Perce Tribe

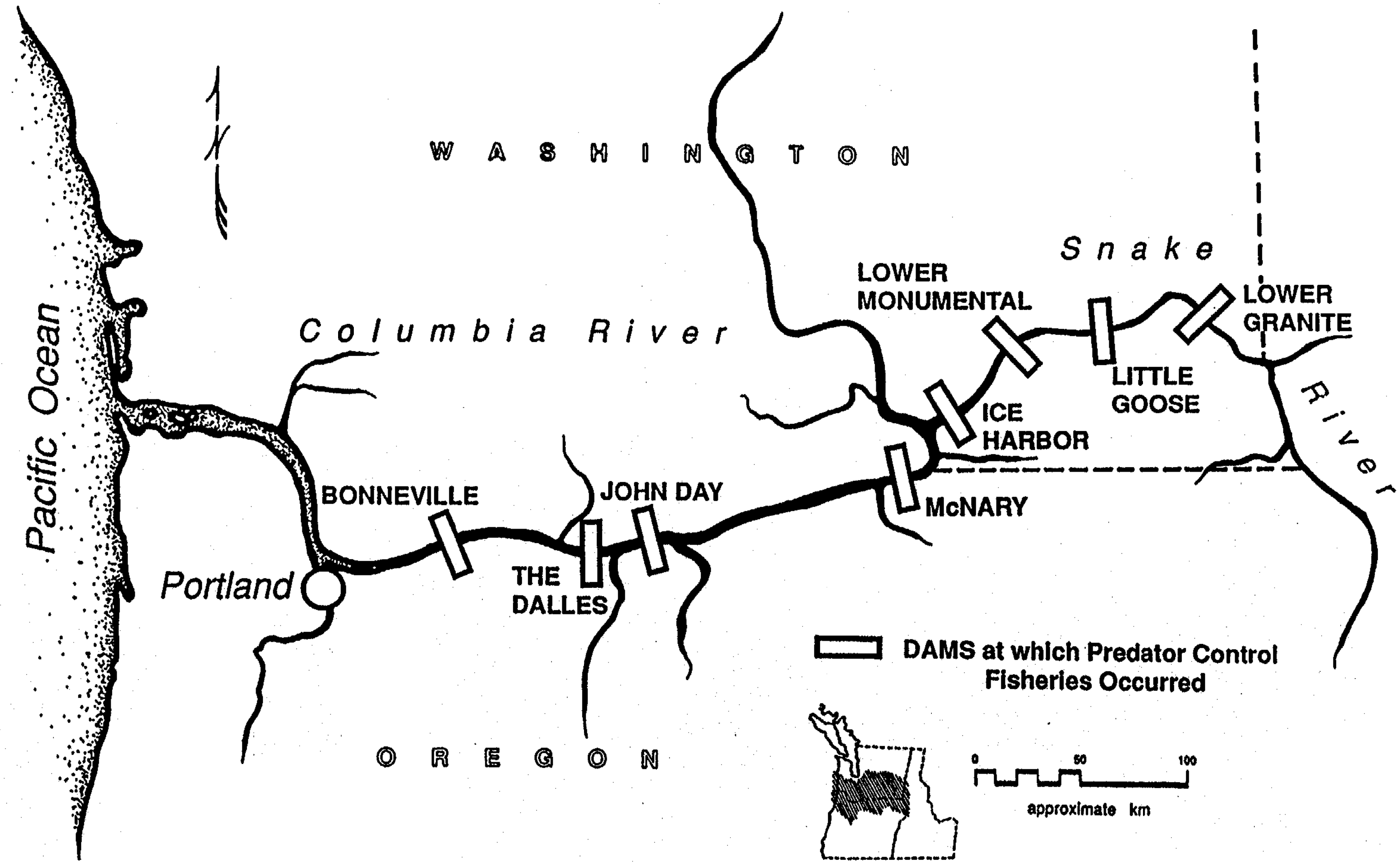


Figure D-1. Dams where controlled angling operations were conducted in 1993.

Table D-2. Supplemental angling activities used in 1993.

Supplemental angling method & personnel source	Dam	Dates
Mobile Crew		
CRITFC	Bonneville, The Dalles, John Day, & McNary	May 25-Sept 16
Volunteer Angling		
NW Steelheaders: Portland Chapter, Tom McCall Chapter	Bonneville	July 10, 17, 24, & Aug 7
The Dalles Rod & Gun Club	The Dalles	June 25, July 16, 23, 30, & Aug 6
The Ladies Angle: High Desert Chapter	McNary	July 10, 24, & Aug 7
Mid Columbia Bass Anglers	McNary	July 17 & Aug 14
Boat Angling		
Warm Springs Tribe	The Dalles	July 21-22, 27-28
	John Day	Aug 11-12
Nez Perce Tribe	Lower Granite	July 21, 26-28, Aug 12, 16-18, 24, & Sept 3
	Little Goose	July 22, Aug 11, 19, 25, & Sept 2
	Lower Monumental	Aug 10
	Ice Harbor	Aug 2
	McNary	Aug 26-27, 31, & Sept 1

We transferred northern squawfish caught to on-site freezers or coolers. Northern squawfish with "spaghetti" tags or radio transmitters were given to the Oregon Department of Fish and Wildlife (ODFW) and U.S. Fish and Wildlife Service (USFWS), respectively. Tagged channel catfish, bass (*Micropterus* spp.), and walleye (*Stizostedion vitreum*) were immediately released after the tag number and capture location were recorded.

We collected and summarized data as in 1992 (Parker et al. 1993). Data were recorded in hand-held computers and transmitted by modem each day to our Portland office. Computer programs filtered incoming data files for anomalous data, which we investigated and corrected, if necessary. Data for all angling types (e.g., dam-based crews, volunteers, boats) were aggregated by dam for weekly reports to ODFW, the contracting agency, and for this report. Channel catfish sacrificed for diet analysis were reported in Release Condition 3 (e.g., dead).

Diet Analysis

We sacrificed approximately 20% of the channel catfish caught incidentally at McNary Dam and Snake River dams (target N $= 5 \cdot dam^{-1} \cdot wk^{-1}$) and removed their digestive tracts for diet analysis. We also sampled the digestive tracts of northern squawfish (target N $= 10 \cdot dam^{-1} \cdot wk^{-1}$ at all eight dams) to provide a relative standard for evaluating the incidence of juvenile salmonids found in channel catfish samples. Sampling rates were not uniform among dams and weeks. The crews, whose schedules (days and hours) varied weekly, generally sampled the first fish caught each week. Sample collection and analysis used the procedures of Collis et al. (1993), except that we injected approximately 50 ml of a saturated sodium bicarbonate solution into each channel catfish sample to neutralize digestive acids that decalcify prey bones. Left pectoral spines were collected (Sneed 1951) from channel catfish for age determination (Marzolf 1955).

RESULTS AND DISCUSSION

Dam Angling

Northern Squawfish Catch

In 1993, anglers fished approximately 9,718[1] h and had a confirmed catch of 16,949[1] northern squawfish, for a seasonal catch per angler hour (CPAH) of 1.7, the same as 1992 (Table D-3). Both total effort and total catch declined approximately 30% from 1992.

We generally succeeded in placing the greatest effort (i.e., angler hours) at dams with the highest catch rates (Figure D-2). Eighty percent of the effort was at Columbia River dams. Unexpected decreases (relative to 1992) in CPAH at The Dalles and McNary dams and the increase at Bonneville Dam (Table D-3) were responsible for some inefficiency. Results of volunteer and boat angling are presented in separate sections below.

Columbia River Dam

In 1993, 7,807 angler hours (18 % decrease from 1992) at Columbia River dams produced 15,944 fish (30% decrease), for a 2.0 seasonal CPAH (17% decrease; Table D-3). Four years of previous removals from consistently productive areas (e.g., the tailraces of The Dalles and McNary dams) probably account for some of the decline in CPAH. The Dalles Dam, which had the highest catch and CPAH of any dam in 1992, had the greatest decline in CPAH (53%, from 3.0 to 1.4) in 1993. Sites near the sluiceway outfall, the most productive in years past, were relatively barren this year. Since 1990, dam anglers have removed 14,850 northern squawfish from the tailrace of The Dalles Dam (Vigg et al. 1990; CRITFC, unpubl. data).

The CPAH at McNary Dam also declined (34%, from 2.9 to 1.9) in 1993, despite splitting the crew and distributing its effort through all days of the week. We hypothesize that CPAH is an inverse function of how intensively effort is focused in space and time (within a limited range of fish abundance and catchability). Therefore, we expect that the McNary Dam CPAH would have been even lower if we had maintained a single large crew on a conventional four-day work week. Dam anglers have removed 24,572 northern squawfish from the tailrace of McNary Dam since 1990 (Vigg et al. 1990; CRITFC, unpubl. data), which may account in part for the decline in CPAH at that dam.

[1] Data reported by the resident crew at John Day Dam through July 11 have been excluded from these results. The effort (angler hours) reported in those data was overstated to an unknown degree, and we were not able to determine if the corresponding catch data were also inaccurate. Excluded data are provided in footnotes for Table C-3.3 and for Appendix Tables C-3.1.4 and C-3.1.13.

Table D-3. Angling effort and northern squawfish catch by dam for 1991, 1992, and 1993.

Dam	1991			1992			1993		
	Seasonal totals			Seasonal totals			Seasonal Totals		
	Hours fished	Northern squaw-fish	CPAH	Hours fished	Northern squaw-fish	CPAH	Hours fished	Northern squaw-fish	CPAH
Columbia River									
Bonneville	2,621	8,131	3.1	1,781	4,814	2.7	1,991	5,836	2.9
The Dalles	1,333	3,674	2.8	2,496	7,561	3.0	1,992	2,712	1.4
John Day	2,816	5,004	1.8	2,775	3,427	1.2	1,044[a]	2,248[a]	2.2[a]
McNary	3,416	8,348	2.4	2,523	7,297	2.9	2,780	5,148	1.9
Season	**10,187**	**25,157**	**2.5**	**9,575**	**23,099**	**2.4**	**7,807**[a]	**15,944**[a]	**2.0**[a]
Snake River									
Ice Harbor	2,052	1,486	0.7	298	278	0.9	404	122	0.3
Lower Monumental	2,472	3,313	1.3	943	475	0.5	396	105	0.3
Little Goose	2,140	4,915	2.3	3,062	1,664	0.5	378	100	0.3
Lower Granite	2,448	4,480	1.8	2,881	2,352	0.8	734	678	0.9
Season	**9,112**	**14,194**	**1.6**	**7,184**	**4,769**	**0.7**	**1,911**	**1,005**	**0.5**
GRAND TOTALS	**19,298**	**39,351**	**2.0**	**16,759**	**27,868**	**1.7**	**9,718**[a]	**16,949**[a]	**1.7**[a]

[a] Does not include 517 h fished and 261 northern squawfish. See text for rationale.

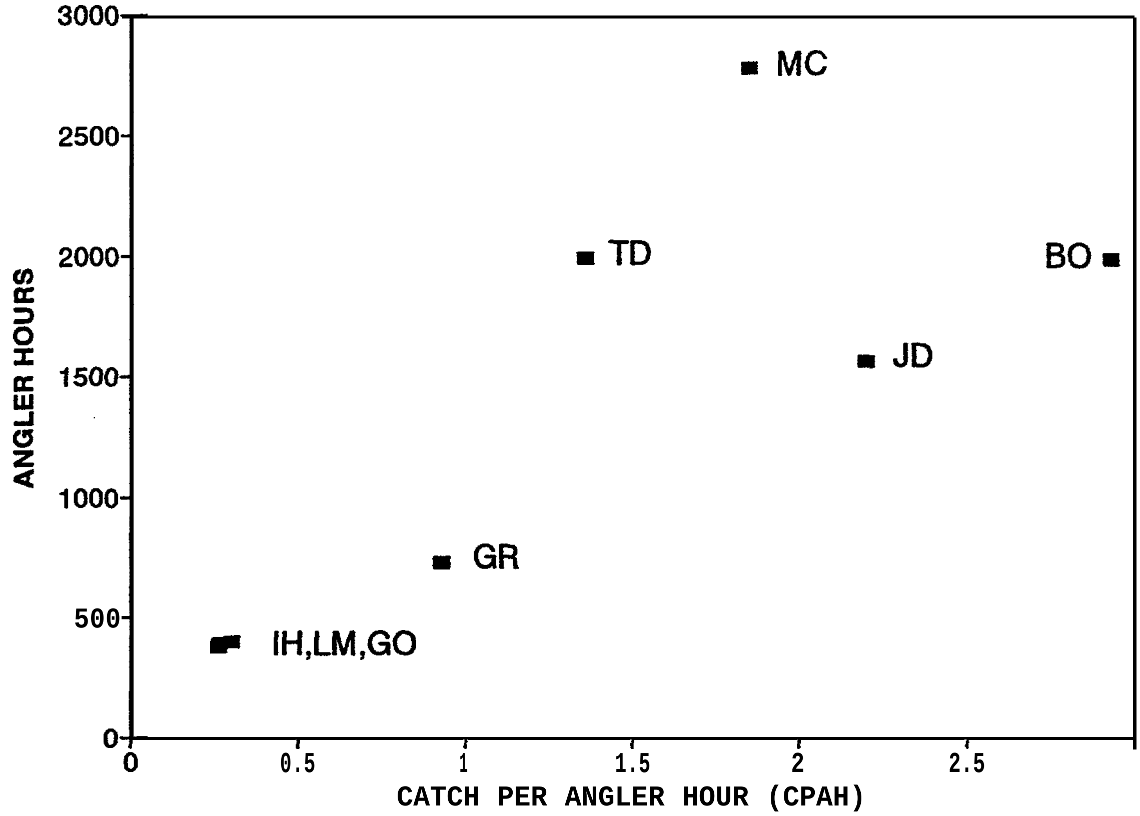


Figure D-2. Plot of seasonal catch per angler hour (CPAH) and total hours fished, by dam for 1993.

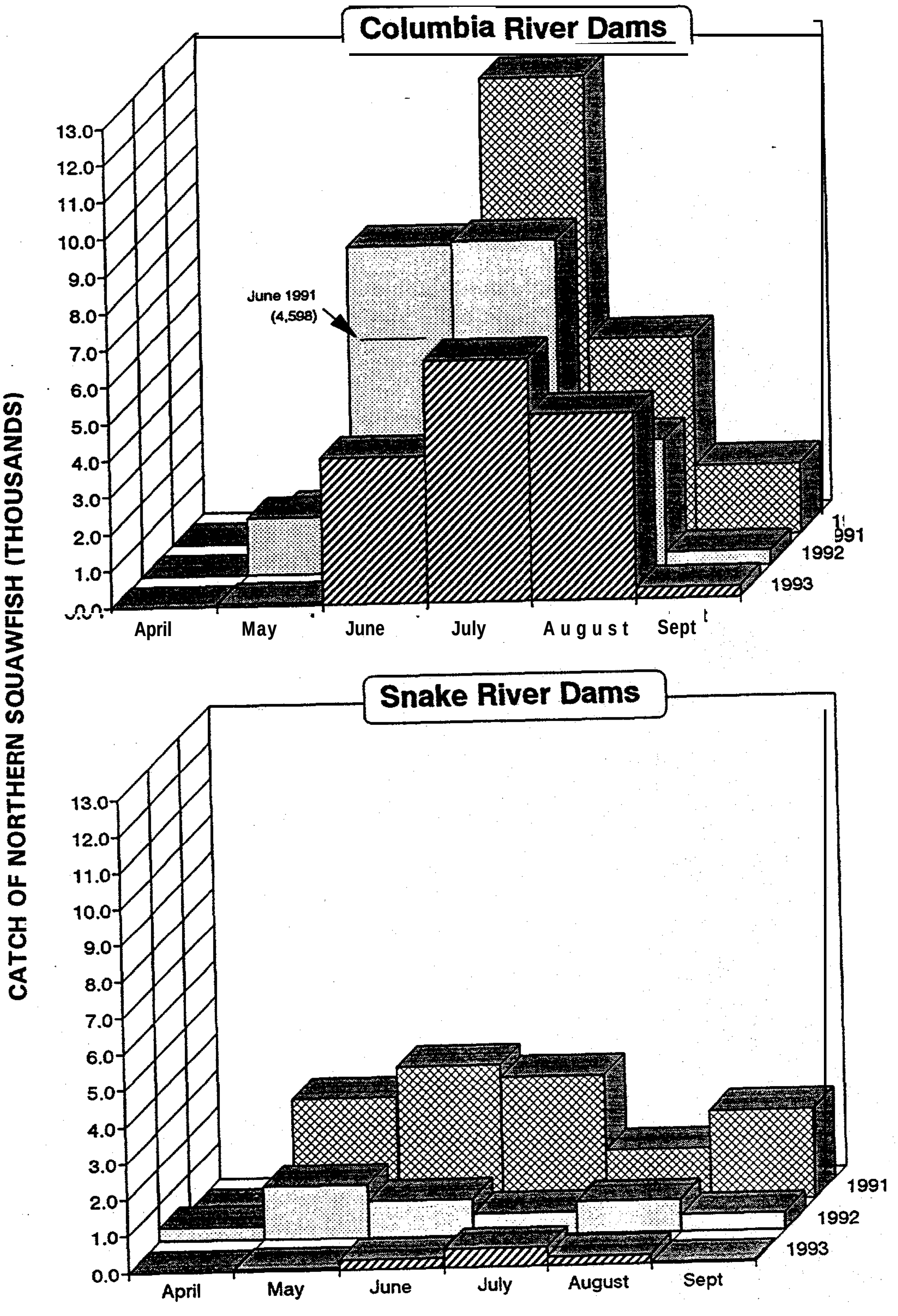


Figure D-3. Monthly catch of northern squawfish at Columbia and Snake River dams for 1991, 1992, and 1993.

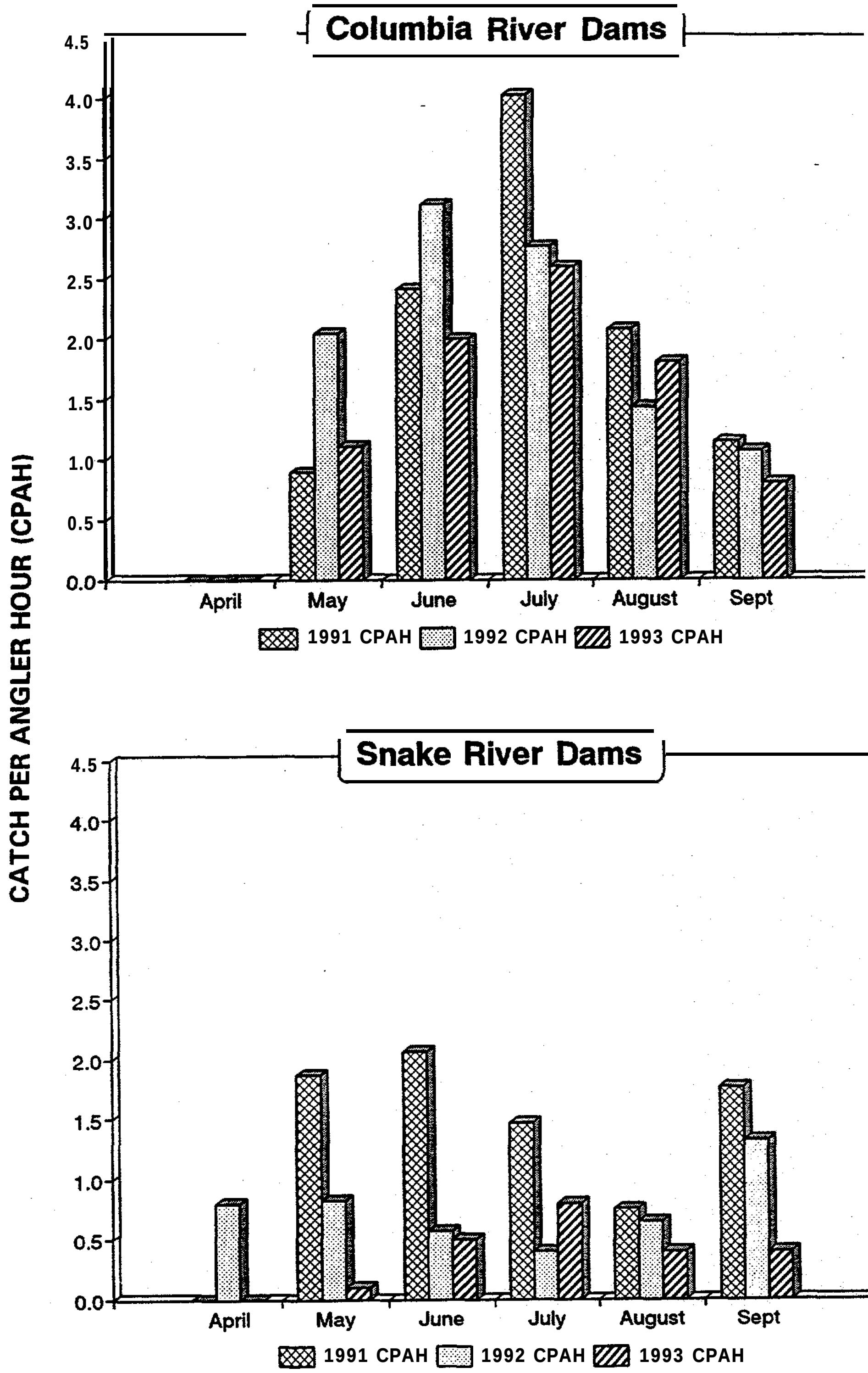


Figure D-4. Monthly average catch per angler hour (CPAH) at Columbia and Snake River dams for 1991, 1992, and 1993.

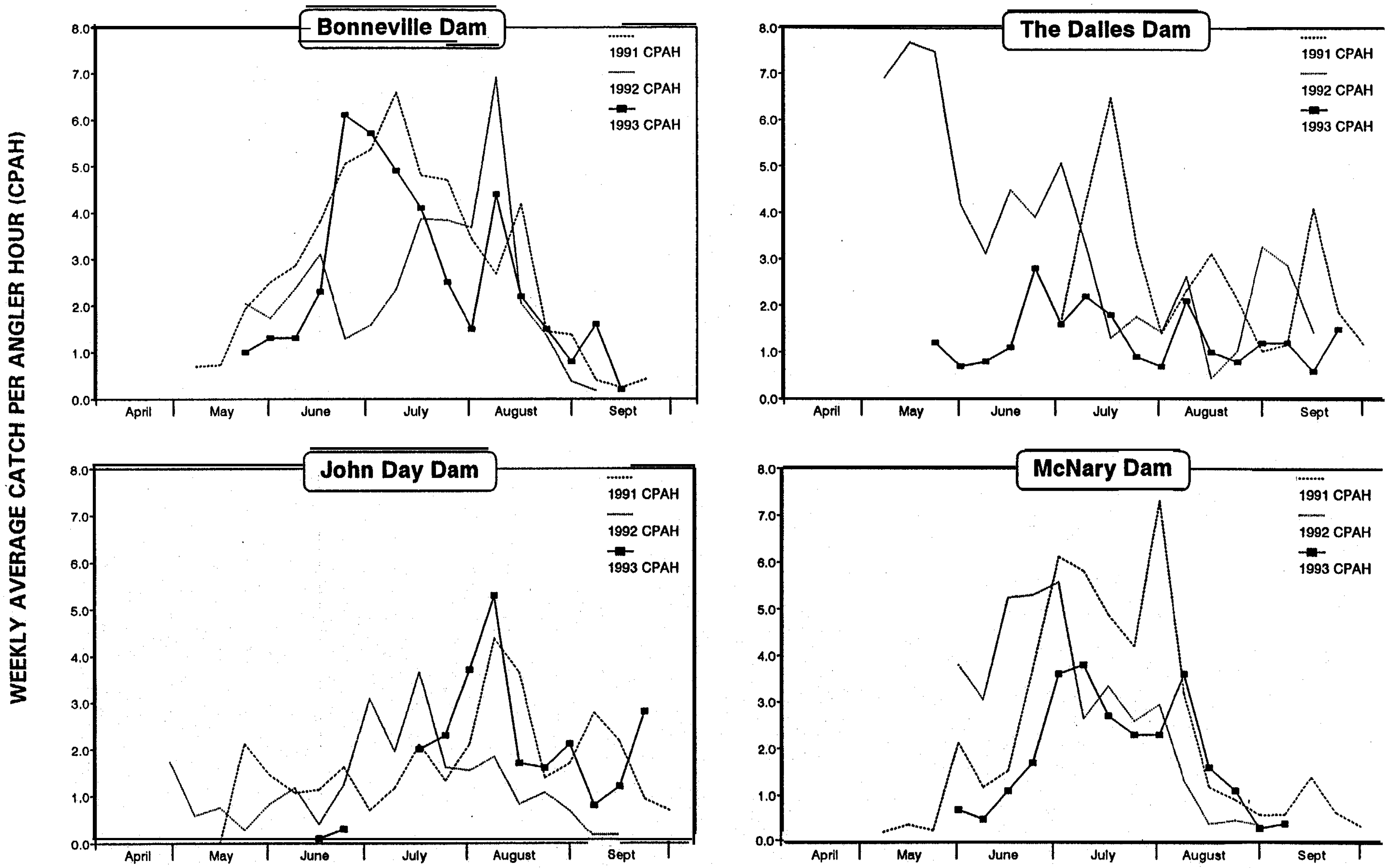


Figure D-5. Weekly average catch per angler hour (CPAH) at Columbia River dams, 1991, 1992, and 1993. Effort varied substantially within and between seasons.

The decline in overall CPAH on the Columbia River was ameliorated in part by a slight increase (7%, from 2.7 to 2.9) at Bonneville Dam and by a substantial increase (83%, from 1.2 fish to 2.2) at John Day Dam. However, the CPAH for John Day Dam would have been lower had part of the data not been excluded.

Environmental conditions, which differed greatly between 1992 and 1993, also may have contributed to the decline in CPAH. Low flows and unseasonably high water temperatures prevailed in the warm, dry spring and summer of 1992. In contrast, 1993 was more like 1991 — cool and wet with higher flow and spill volumes — which may explain the similarities in seasonal trends in catch and CPAH (four dams, combined) between the two years (Figures D-3 and D-4). Likewise, the trend in 1993 weekly average CPAH at individual dams remarkably resembles the trend for 1991, except at The Dalles Dam (Figure D-5). Environmental conditions, such as water temperature and flow, seem to have a strong effect on seasonal trends in CPAH.

The effects of flow were particularly apparent in 1993. Anglers sometimes were frustrated by swift currents and low catches in tailrace sites that had been productive in 1992. Radio-tagged northern squawfish moved away from The Dalles and John Day dams during the period of high flows (R. Shively, USFWS, personal communication), making those fish inaccessible to dam anglers. An earlier study in the tailrace at McNary Dam showed that northern squawfish avoid high velocities (Faler et al. 1988.). Anglers at The Dalles and Bonneville dams observed that during high flows they would catch northern squawfish in small schools or pockets close to tailrace riprap. One such pocket, along the Bradford Island shore of the spill basin at Bonneville Dam, was so specific that an angler fishing in one spot would catch three to five times as many fish as anglers less than 10 m away on either side. Anglers spent much time searching for these small pockets of northern squawfish during high flow periods in 1993.

Very local conditions also affected catches at John Day Dam. Anglers there were generally most successful when spilling began in the evening (G. Lee and S. Parker, YIN, personal communication), catching most of their fish just beyond the edge of the spill turbulence that spread southward across the powerhouse tailrace.

Snake River Dams

The combined catch at Snake River dams (1,005 fish) was 79% lower than in 1992, mostly because of a large (73%) reduction in effort and a moderate (21%) decline in CPAH (to 0.5) in 1993 (Table D-3). We have reduced effort at Snake River dams each year since 1991 as catch rates have continued to decline, and 1993 efforts at the three lower dams (Ice Harbor, Lower Monumental, and Little Goose) were little more than monitoring. Only at Lower Granite Dam did CPAH stay relatively unchanged (0.9 in 1993, 0.8 in 1992) and close to our arbitrary threshold for acceptability (e.g., 1.0). Lower Granite Dam's CPAH probably could not have been sustained without the large reduction (75%) in effort there compared to 1992, assuming that catch rate is inversely related to effort.

We cannot easily account for the continuing decline in CPAH at Snake River dams (Figure D-4; Table D-3). Trends in weekly CPAH for each dam reveal little (Figure D-6), except that Lower Granite Dam had an unusually prominent summer (July)-mode,. which is more characteristic of a Columbia River dam. As in the Columbia, unusually high flows, low water temperatures, and high turbidity persisted through June and probably depressed catch rates during that period, at least at Lower Granite and Little Goose dams (M. Villalobos, NPT, personal communication). University of Idaho researchers informed the angling crew at Lower Granite Dam that many of the radio-tagged northern squawfish released into the tailrace of that dam moved downstream l-3 km and stayed there when flows and turbidity were high (M. Villalobos, NPT, personal communication). Catch rates at Snake River dams in 1991 dropped dramatically during a turbid spate in May of that year (Beaty et al. 1993). Also, removal of northern squawfish over the last three years (approximately 20,000 by dam angling alone) has probably contributed to the large (69%) decline in CPAH at Snake River dams since 1991.

Volunteer Angling

Volunteers fished 266 hours (2.7% of all effort) and caught 550 northern squawfish (3.2% of total catch), for a seasonal CPAH of 2.3. Although we believe that volunteer angling, coordinated and supervised in 1993 by CRITFC employees, was more cost effective than conventional dam angling, we do not yet have data to confirm that belief.

Volunteers were not consistently more or less effective than resident crews at the dams (Table D-4). At Bonneville Dam, Corps of Engineer safety constraints did not allow volunteers to fish in riprap areas, where the resident crew catches were relatively high. At The Dalles Dam, evening hours fished by the volunteers apparently were more productive than the daytime hours, which the resident crew preferred to fish.

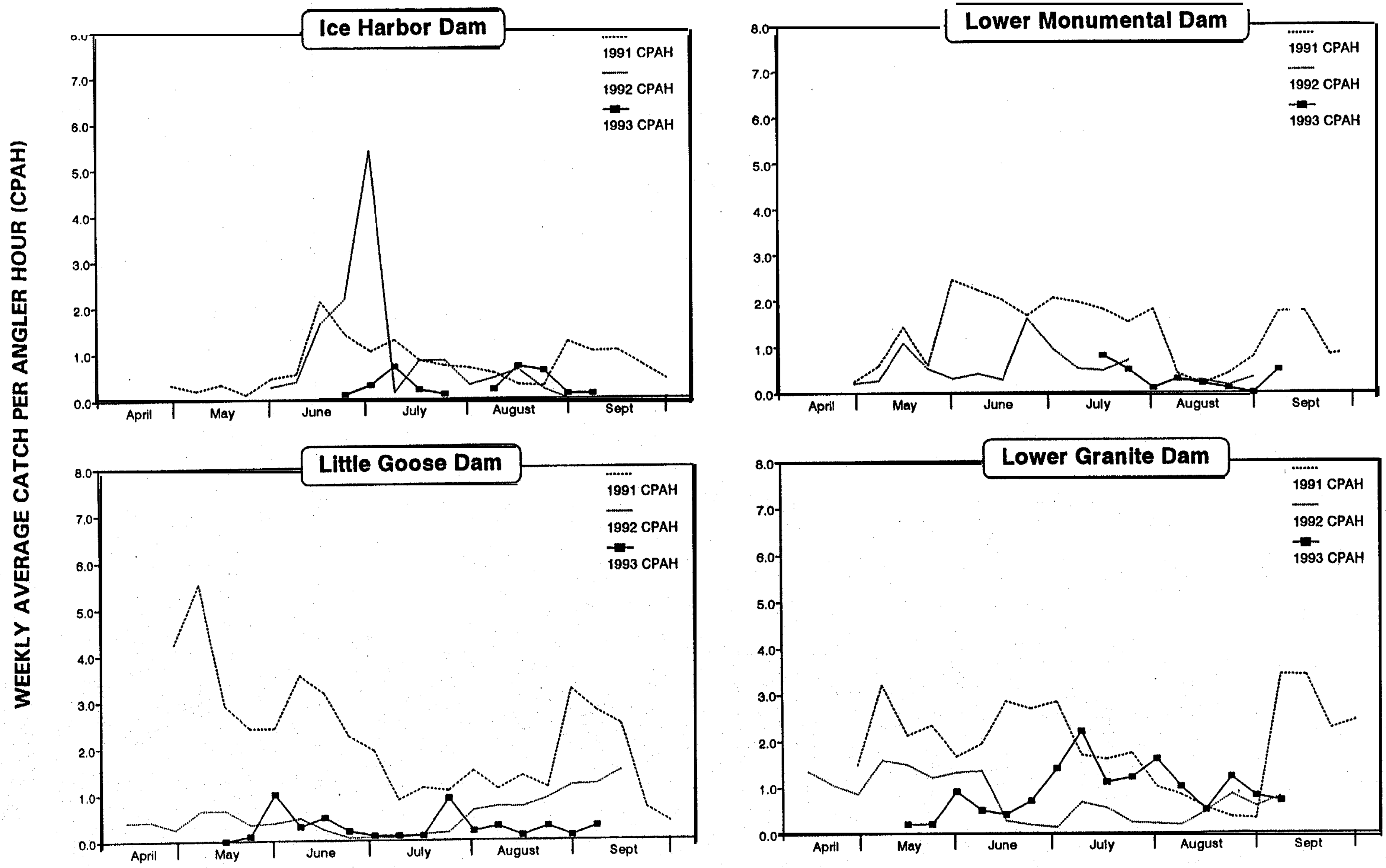


Figure D-6. Weekly average catch per angler hour (CPAH) at Snake River dams, 1991, 1992, and 1993. Effort varied substantially within and between seasons.

Table D-4. Comparison of daily CPAH values for the volunteer anglers with the corresponding weekly CPAH for the resident crew.

	Volunteer anglers			Resident crew	
Dam	Volunteer group	Date	CPAH	Week	CPAH
Bonneville	Portland NW Steelheaders	7/10/93	2.6	28	4.8
	Tom McCall NW Steelheaders	7/17/93	0.5	29	4.9
	Portland NW Steelheaders	7/24/93	2.4	30	2.1
	Tom McCall NW Steelheaders	8/7/93	1.9	32	5.5
	Combined CPAH		**2.0**		**4.3**
The Dalles	The Dalles Rod & Gun Club	6/25/93	2.3	26	2.5
	The Dalles Rod & Gun Club	7/16/93	3.7	29	1.3
	The Dalles Rod & Gun Club	7/23/93	3.1	30	0.7
	The Dalles Rod & Gun Club	7/30/93	1.5	31	0.5
	The Dalles Rod & Gun Club	8/6/93	2.5	32	2.2
	Combined CPAH		**2.6**		**1.5**
McNary	The Ladies Angle	7/10/93	2.2	28	4.0
	Mid-Columbia Bass Anglers	7/17/93	2.6	29	2.7
	The Ladies Angle	7/24/93	2.1	30	2.3
	The Ladies Angle	7/31/93	3.8	31	2.2
	Mid-Columbia Bass Anglers	8/14/93	0.3	33	1.7
	Combined CPAH		**2.2**		**2.5**
Seasonal CPAH			**2.3**		**2.7**

Probably the greatest benefit of the volunteer program has been the productive and amicable cooperation between members of two groups (sport anglers and treaty tribes) whose interests have conflicted at times. Negative stereotypes usually began to dissipate with close personal contact and cooperation on the dams. Volunteers and tribal participants wish to continue this program.

Because of the volunteer angling program, several dozen members of the public, few of whom had participated in the sport-reward fishery, have learned about and become involved in the predator control program and other Columbia River fishery management issues. Pre-season and postseason meetings with the angling groups have provided many opportunities to share information. Also, we often took short breaks during evenings of angling to let the volunteers observe smolt monitoring and other fish-related activities not normally available to the public. Corps personnel at the three dams (Bonneville, The Dalles, and John Day) were very accommodating and generally satisfied with how the volunteer program was conducted. The volunteer program could probably be expanded two or threefold, although doing so would require more project management resources than are available.

Boat Angling

Boat angling was implemented to target northern squawfish that were close to the dams, but inaccessible to dam-based anglers (Parker et al. 1992). We did not begin boat angling in 1993 until midseason, primarily because of unresolved insurance issues and other demands (e.g., from the Merwin trapping fishery) for boats and personnel. At least one day of boat angling was conducted in 1993 at each dam except Bonneville (Table D-5).

Although the average CPAH for boat angling was generally higher (The Dalles Dam excepted) than dam-based anglers on the same days (Table D-S), we cannot conclude that boat angling is more efficient than dam-based angling. The amount and distribution of boat angling effort was not sufficient for a good evaluation at any dam in any month. Also, the data shown in Table D-5 are sometimes based on very low catches, such as for the single days of sampling at Ice Harbor Dam and Lower Monumental Dam, when catches-by all anglers totaled only eight and four fish, respectively. The relatively high costs of boat operations (e.g., fuel and insurance) would also have to be considered in a thorough evaluation. Also, boat operations in the BRZ are restricted to daylight hours, which precludes boat angling during crepuscular and nighttime hours when dam-based angling often is very productive.

Table D-S. CPAH of boat angling and dam angling crews on the same days and dams.

Dam	Date	Boat crew	CPAH Boat	CPAH Dam
The Dalles	21-Jul-93	CTWS	0.2	0.7
	22-Jul-93		0.1	0.6
	28-Jul-93		0.1	1.0
	29-Jul-93		0.0	0.3
	Combined		0.1	0.7
John Day	11-Aug-93	CTWS	2.2	0.4
	12-Aug-93		3.6	0.8
	Combined		3.0	0.6
McNary	26-Aug-93	NPT	0.3	0.4
	27-Aug-93		1.1	0.3
	31-Aug-93		1.8	0.4
	01-Sep-93		1.7	0.2
	Combined		1.2	0.3
Ice Harbor	02-Aug-93	NPT	0.5	0.2
Lower Monumental	10-Aug-93	NPT	0.2	0.1
Little Goose	22-Jul-93	NPT	1.5	0.0
	ll-Aug-93		0.1	0.1
	19-Aug-93		0.3	0.3
	25-Aug-93		0.0	0.1
	02-Sep-93		0.4	0.1
	Combined		0.3	0.1
Lower Granite	21-Jul-93	NPT	3.3	1.2
	26-Jul-93		2.2	1.1
	27-Jul-93		2.4	0.9
	28-Jul-93		1.4	1.3
	12-Aug-93		0.5	0.4
	16-Aug-93		0.3	0.2
	17-Aug-93		1.3	2.1
	18-Aug-93		1.6	1.6
	24-Aug-93		0.8	0.8
	03-Sep-93		0.3	1.2
	Combined		1.4	1.1

Incidental Catch

We caught fewer incidental fish (986; Appendix Table D-l. 11) than in 1992 (1,706; Parker et al. 1993), and they composed a slightly lower percentage of the catch (5.5%; Appendix Table D-l. 10 and Figure D-7) than in 1992 (5.8 % ; Parker et al. 1993). The percentage of bass (*Micropterus* spp.) roughly doubled from 1 .O% in 1992 (Parker et al. 1993) to 2.1% (Appendix Table D-l. 10). Most of the increased bass catch (over 200 more fish) occurred at The Dalles Dam, where anglers abandoned formerly productive sites (e.g., the sluiceway outfall) and prospected for northern squawfish in other areas where bycatch happened to be higher. *The* percentage of catfish (*Ictalurus* spp.) declined from 3.7% in 1992 (Parker et al. 1993) to 2.1% in 1993 (Appendix Table D-l. 10).

We caught three juvenile and three adult salmonids (Appendix Table D-l. 11). All except one juvenile chinook salmon (*Oncorhynchus tshawytscha*; caught August 8, 1993, at McNary Dam) were released in good condition.

Diet Analysis

The digestive tracts of 72 channel catfish caught incidentally at McNary Dam and the four Snake River dams from June through August contained only two juvenile salmonids, for a weighted mean of 0.05 juvenile salmonids per channel catfish (Table D-6). This is approximately one-third of the weighted mean number of juvenile salmonids (0.16) found in northern squawfish at the same dams in the same months (Table D-6). Detailed results of the diet analysis are in Appendix Tables D-l. 16 through D-l .29, which also include data for northern squawfish sampled during other months and at the other three dams.

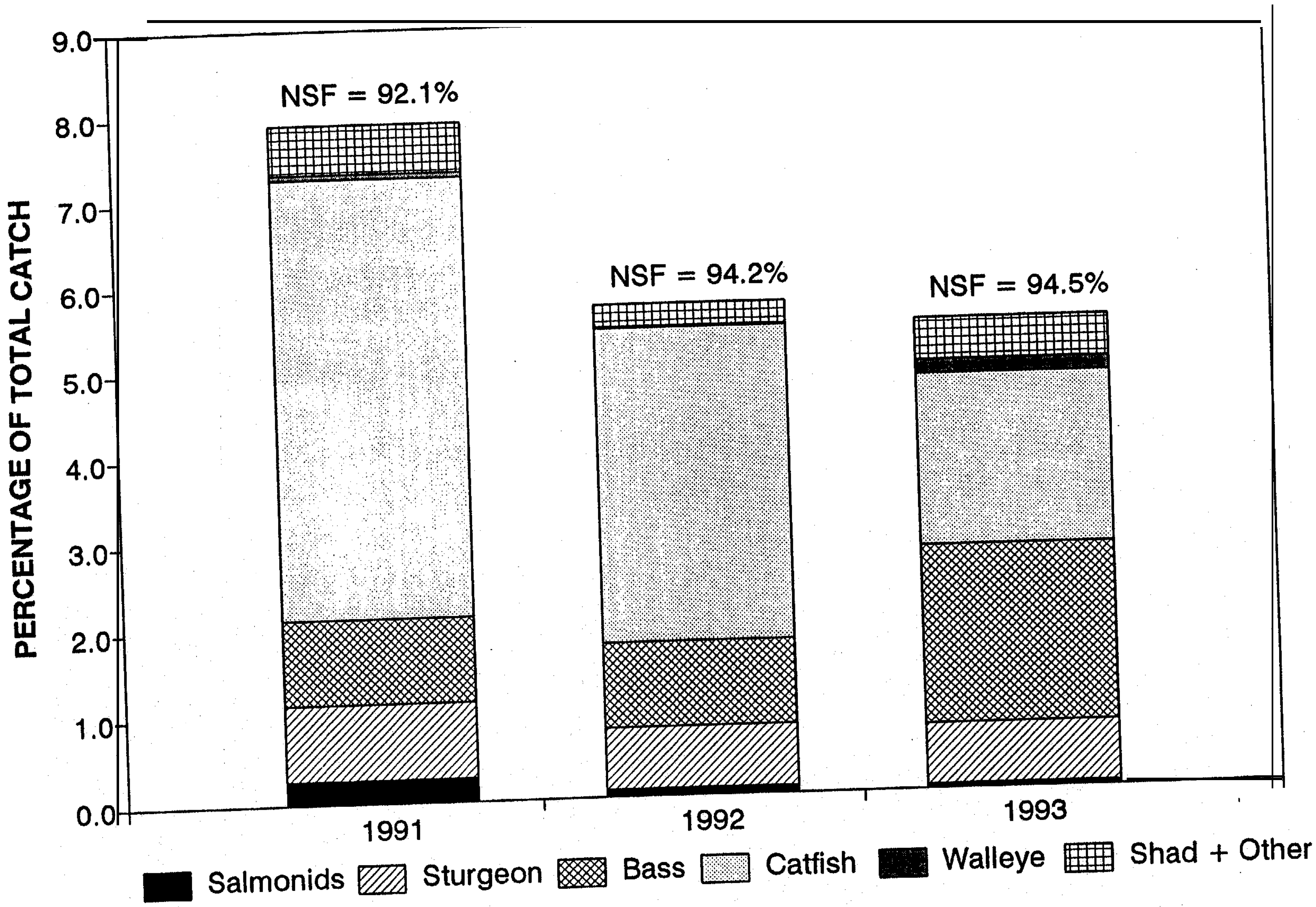


Figure D-7. Percentage of total catch of all incidentally caught fish and northern squawfish (NSF) at Columbia and Snake River dams during 1991, 1992, and 1993.

Table D-6. Incidence of juvenile salmonids (Sal.) in digestive tracts of channel catfish and northern squawfish at McNary Dam and Snake River dams in 1993. Mean number of juvenile salmonids per predator (Mean Sal.) are weighted by catch (Wtd. Mean Sal.).

		Channel Catfish					Northern Squawfish				
Dam	Mo	Catch	*N*	No. Sal.	Mean Sal.	Wtd. Mean Sal.	Catch	*N*	No. Sal.	Mean Sal.	Wtd. Mean Sal.
McNary	Jun	47	11	1	0.09	*0.07*	1273	30	12	0.40	*0.19*
	Aug	13	3	0	0		1459	15	0	0	
Ice Harbor	Jun	15	9	0	0	0.07	10	8	0	0	0
	Jul	89	9	1	0.11		61	12	0	0	
	Aug	33	3	0	0		51	11	0	0	
Lower Monumental	Jul	10	2	0	0	0	60	15	9	0.60	0.36
	Aug	75	23	0	0		45	21	1	0.05	
Little Goose	Jun	4	1	0	0	0	64	16	0	0	0
	Jul	1	1	0	0		13	4	0	0	
	Aug	3	1	0	0		15	5	0	0	
Lower Granite	Jun	21	8	0	0	0	182	24	1	0.04	0.05
	Jul	7	1	0	0		356	19	1	0.05	
Snake River Dams			**58**	**1**	**--**	**0.04**		**135**	**12**	**--**	**0.08**
ALL DAMS			**72**	**2**	**--**	**0.05**		**180**	**24**	**--**	**0.16**

These results must be interpreted carefully. We assumed that regurgitation was negligible, although we could not evaluate that assumption. The two juvenile salmonids found in channel catfish could have been dead or moribund prey that were scavenged. This possiblity is supported by the fishing method being used when the channel catfish were caught. Most channel catfish sampled were caught using smolt bait, which is often fished on or near the river bottom, where northern squawfish are frequently caught. Also, our sampling was probably selective for the smaller, perhaps less predaceous, channel catfish. Many large (> 600 mm) fish broke the line as they were lifted from the water; the mean length of channel catfish sampled was 448 mm. Channel cattish > 400 mm are more piscivorous than smaller fish (Poe et al. 1991). These results may not accurately represent our entire catch because sampling was inconsistent (i.e., we lack samples for some months) and sampling rates varied greatly. Although same-place, same-month samples from northern squawfish may be a relatively meaningful standard, we cannot assume that differences in the contents of their digestive tracts reflect differences in consumption rates. Digestive tract evacuation rates, for example, may differ between the two species.

The incidence of juvenile salmonids in predator digestive tracts is very much a function of prey abundance. For example, the incidence of juvenile salmonids in northern squawfish caught at Lower Monumental Dam (0.36 overall), particularly in July (0.60), was very high relative to other Snake River dams in the same months (Table D-6). Five of the nine juvenile salmonids found in July bore coded-wire tags (Code 63-50-12) identifying them as Snake River fall chinook salmon released at Lyons Ferry Hatchery, 23 km upstream from the dam. The paucity of summer-migrating salmonids in the Snake River probably accounts for their low incidence in samples from other Snake River dams.

Low incidence is not equivalent to low predation rate, however. A species at low abundance, such as wild summer-migrating Snake River fall chinook salmon, could suffer very high rates of predation mortality with very low probability that methods such as ours would detect any of it.

The high incidence of Lyons Ferry fall chinook salmon in samples from Lower Monumental Dam suggests a predation problem on these summer-released fish. Two hundred thousand subyearling fall chinook salmon were released between June 21 and June 25 [Fish Passage Center (FPC) Weekly Report #93-17], 2.5-3 weeks before we began sampling at Lower Monumental Dam. Although the first Lyons Ferry fish passed Lower Monumental Dam a few days after release, many took weeks to move the short distance to the dam (FPC 1993). During those weeks of residence and slow migration, predation rates may have been very high.

RECOMMENDATIONS

1. Continue controlled angling at all eight dams and modify effort to improve efficiency:

Dam	Anglers	Season & effort pattern
Bonneville	5	Late May-June through August
The Dalles	5	Late May-June through August
John Day	4	Mid June through early Sept.
McNary	8	June through August
Ice Harbor/ L. Monumental/ Little Goose/ Lower Granite	4	June through July; all dams staffed by a single crew.

2. Retain the mobile crew to augment resident crew efforts at the most productive Columbia River dams.

3. Continue limited use of boat angling and carefully evaluate its effectiveness when and where used.

4. Continue the volunteer angling at Bonneville, The Dalles, and McNary dams.

5. Continue to develop and refine effective angling strategies, including fishing techniques, lures and bait, and schedules.

6. Coordinate with U.S. Army Corps of Engineer biologists regarding the replacement of existing bird wires and the installation of new wires.

7. Continue analyzing data to better understand the factors affecting catch rates.

REFERENCES

Beaty, R. E., B. L. Parker, K. Collis, and K. McRae. 1993. The use of controlled angling to manage northern squawfish populations at selected dams on the Columbia and Snake rivers. Pages 111-185 *in* C. F. Willis and A. A. Nigro, editors. Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1991 Annual Report. Contract DE-BI70-90BP07084, Bonneville Power Administration, Portland, Oregon.

Bennett, D. H., P. M. Bratovich, W. Knox, D. Palmer, and H. Hansel. 1983. Status of the warmwater fishery and the potential of improving warmwater fish habitat in the Lower Snake reservoirs. Final Report. Contract DACW68-79-C0057, U.S. Army Corps of Engineers, Walla Walla, Washington.

Bentley, W. W., and H. L. Raymond. 1976. Delayed migrations of yearling chinook salmon since completion of Lower Monumental and Little Goose dams on the Snake River. Transactions of the American Fisheries Society 105:422-424.

Faler, M. P., L. M. Miller, and K. I. Welke. 1988. Effects of variation in flow on distributions of northern squawfish in the Columbia River below McNary Dam. North American Journal of Fisheries Management 8:30-35.

FPC (Fish Passage Center). 1993. Weekly reports #93-10 through #93-28. Portland, Oregon.

Marzolf, R. C. 1955. Use of pectoral spine and vertebrate for determining age and rate of growth of the channel catfish. Journal of Wildlife Management 19:243-249.

Parker, B. L., K. Collis, B. Ashe, R. E. Beaty, and K. McRae. 1993. Controlled angling for northern squawfish at selected dams on the Columbia and Snake rivers in 1992. Pages 129-182 *in* C. F. Willis and A. A. Nigro, editors. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1992 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

Petersen, J. H. In review. Juvenile salmonid losses to northern squawfish in the Columbia River: How important is the spatial pattern used to subdivide a reservoir? (available from the author: National Biological Survey, Columbia River Field Station, Cook, Washington, 98605).

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405-420.

Raymond, H. L. 1988. Effects of hydroelectric development and fisheries enhancement on spring and summer chinook salmon and steelhead in the Columbia River Basin. North American Journal of Fisheries Management 8:1-24.

Rieman, B. E., R. C. Beamesderfer, S. Vigg, and T. P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:448-458.

Sneed, K. E. 1951. A method for calculating growth of channel catfish, *Ictalurus lacustrus punctatus*. Transactions of the American Fisheries Society 80: 174-183.

Vigg, S., C. C. Burley, D. L. Ward, C. Mallette, S. Smith, and M. Zimmerman. 1990. Development of a system-wide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin. Pages 7-l 11 *in* A. A. Nigro, editor. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. Annual Report 1990. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

APPENDIX D-l

Tabular Data

Appendix Table D-1.1. Statistical week numbers and corresponding 1993 dates.

Week number	Corresponding dates
21	May 16-May22
22	May 23 - May 29
23	May 30 - June 5
24	June 6 - June 12
25	June 13 - June 19
26	June 20 - June 26
27	June 27 - July 3
28	July 4 - July 10
29	July 11 - July 17
30	July 18 - July 24
31	July 25 - July 31
32	August 1 - August 7
33	August 8 - August 14
34	August 15 - August 21
35	August 22 - August 28
36	August 29 - September 4
37	September 5 - September 11
38	September 12 - September 18

Appendix Table D-1.2. Weekly average CPAH at **Bonneville Dam,** 1993.

Statistical week number[a]	Total hours fished	Number of northern squawfish	CPAH
22	24	24	1.0
23	56	71	1.3
24	126	160	1.3
25	99	230	2.3
26	95	577	6.1
27	135	771	5.7
28	202	987	4.9
29	210	863	4.1
30	182	461	2.5
31	154	227	1.5
32	162	707	4.4
33	121	261	2.2
34	116	172	1.5
35	178	136	0.8
36	115	185	1.6
37	16	4	0.2
Season	**1991**	5836	2.9

[a] See Appendix Table D-1. 1 for dates associated with statistical weeks.

Appendix Table D-1.3. Weekly average CPAH at The **Dalles Dam,** 1993.

statistical week **number**[a]	Total hours fished	Number of northern squawfish	**CPAH**
22	22	26	1.2
23	89	63	0.7
24	167	126	0.8
25	140	151	1.1
26	181	514	2.8
27	153	246	1.6
28	98	211	2.2
29	140	255	1.8
30	157	148	0.9
31	164	109	0.7
32	154	328	2.1
33	145	148	1.0
34	152	127	0.8
35	111	130	1.2
36	100	116	1.2
37	18	11	0.6
38	2	3	1.5
Season	**1993**	**2712**	**1.4**

[a] See Appendix Table D-l. 1 for dates associated with statistical weeks.

Appendix Table D-1.4. Weekly average CPAH at **John Day Dam,** 1993.

statistical week **number**[a]	Total hours fished	Number of northern squawfish	CPAH
24	--[b]	--[b]	--[b]
25	22[b]	2[b]	0.1[b]
26	20[b]	6[b]	0.3[b]
27	--[b]	--[b]	--[b]
28	--[b]	--[b]	--[b]
29	104	208	2.0
30	101	230	2.3
31	75	278	3.7
32	102	545	5.3
33	144	245	1.7
34	145	234	1.6
35	113	241	2.1
36	150	125	0.8
37	35	43	1.2
38	33	91	2.8
Season	**1044**	2248	**2.2**

[a] See Appendix Table D-1.1 for dates associated with statistical weeks.
[b] Data reported by the resident John Day crew for weeks 24, 25, 26, 27, and 28 are not included, but are listed in the table below.

Statistical week number	Hours fished	Northern squawfish
24	35	8
2.5	116	19
26	119	59
27	146	108
28	101	67

Appendix Table D-1.5. Weekly average CPAH at McNary Dam, 1993.

Statistical week number[a]	Total hours fished	Number of northern squawfish	CPAH
23	90	64	0.7
24	151	73	0.5
25	213	233	1.1
26	185	306	1.7
27	231	824	3.6
28	178	684	3.8
29	208	555	2.7
30	191	431	2.3
31	212	485	2.3
32	222	791	3.6
33	199	310	1.6
34	200	212	1.1
35	296	100	0.3
36	205	80	0.4
Season	**2781**	**5148**	**1.9**

[a] See Appendix Table D-1. 1 for dates associated with statistical weeks.

Appendix Table D-1.6. Weekly average CPAH at **Ice Harbor Darn,** 1993.

statistical week **number**[a]	Total hours fished	Number of northern squawfish	CPAH
26	44	3	0.1
27	63	16	0.3
28	63	43	0.7
29	40	7	0.2
30	39	2	0.1
31	0	0	--
32	47	9	0.2
33	34	23	0.7
34	29	16	0.6
35	18	1	0.1
36	26	2	0.1
Season	403	122	0.3

[a] See Appendix Table D-l. 1 for dates associated with statistical weeks.

Appendix Table D-1.7. Weekly average CPAH at **Lower Monumental Dam,** 1993.

statistical week **number**[a]	Total hours fished	Number of northern squawfish	CPAH
29	25	19	0.8
30	51	27	0.5
31	**99**	14	0.1
32	**49**	15	0.3
33	53	11	0.2
34	77	7	0.1
35	17	0	0.0
36	24	12	0.5
Season	**395**	**105**	0.3

[a] See Appendix Table D-l. 1 for dates associated with statistical weeks.

Appendix Table D-1.8. Weekly average CPAH at **Little Goose Darn,** 1993.

statistical week **number**[a]	Total hours fished	Number of northern squawfish	CPAH
21	34	**0**	**0.0**
22	22	3	0.1
23	23	24	1.0
24	40	11	0.3
25	41	19	0.5
26	40	8	0.2
27	35	4	0.1
28	20	2	0.1
29	18	1	0.1
30	7	6	0.9
31	10	2	0.2
32	24	8	0.3
33	20	2	0.1
34	14	4	0.3
35	14	1	0.1
36	18	5	0.3
Season	380	**100**	0.3

[a] See Appendix Table D- 1. 1 for dates associated with statistical weeks.

Appendix Table D-1.9. Weekly average CPAH at **Lower Granite Dam,** 1993.

statistical week **number**[a]	Total hours fished	Number of northern squawfish	CPAH
21	56	11	0.2
22	63	10	0.2
23	52	42	0.8
24	42	19	0.5
25	47	20	0.4
26	50	33	0.7
27	47	68	1.4
28	44	95	2.2
29	73	83	1.1
30	60	72	1.2
31	67	106	1.6
32	25	24	1.0
33	22	10	0.5
34	53	62	1.2
35	19	15	0.8
36	12	8	0.7
Season	732	678	0.9

[a] See Appendix Table D-1. 1 for dates associated with statistical weeks.

Appendix Table D-1.10. Monthly species composition of dam angling catch for **Columbia and Snake** river dams, 1993.

Month	Percent northern squawfish in total catch	Percent incidental species in total catch	Percent of total catch (all species)						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
COLUMBIA R.									
May	86.21	13.79	1.72	0.00	8.62	0.00	0.00	1.72	1.72
June	94.26	5.74	0.07	0.97	2.42	1.52	0.00	0.28	0.47
July	96.73	3.27	0.01	0.54	2.15	0.24	0.03	0.16	0.13
August	96.52	3.48	0.02	0.67	1.53	0.32	0.44	0.29	0.21
September	90.49	9.51	0.00	0.61	4.29	0.00	1.84	1.53	1.23
Season	**95.88**	**4.12**	**0.04**	**0.69**	**2.09**	**0.58**	**0.19**	**0.26**	**0.27**
SNAKE R.									
May	96.00	4.00	0.00	4.00	0.00	0.00	[illegible]	0.00	0.00
June	82.58	17.42	0.00	1.29	3.23	12.90	[illegible]	0.00	0.00
July	79.93	20.07	0.00	0.98	1.47	17.46	[illegible]	0.00	0.16
August	64.53	35.47	0.00	0.58	1.74	33.14	[illegible]	0.00	0.00
September	92.86	7.14	0.00	0.00	0.00	7.14	[illegible]	0.00	0.00
Season	**76.95**	**23.05**	**0.00**	**1.00**	**1.91**	**20.06**	**[illegible]**	**0.00**	**0.08**
GRAND TOTAL									
May	89.16	10.84	1.20	1.20	6.02	0.00	0.00	1.20	1.20
June	93.46	6.54	0.07	0.99	2.47	2.30	0.00	0.27	0.44
July	95.34	4.66	0.01	0.58	2.09	1.66	0.03	0.15	0.13
August	94.55	5.45	0.02	0.66	1.54	2.35	0.41	0.27	0.20
September	90.59	9.41	0.00	0.59	4.12	0.29	1.76	1.47	1.18
Season	**94.50**	**5.50**	**0.03**	**[illegible]**	**2.07**	**2.00**	**0.17**	**0.25**	**0.26**

Appendix Table D-1.11. Monthly catch of incidental species by condition at release for Columbia and Snake river dams, 1993. Condition codes: 1) minimal injury, certain to survive; 2) moderate injury, may or may not survive; 3) dead, nearly dead, or certain to die; L) line cut or broken, fish not removed from the water. Catfish sacrificed for diet samples are included as condition 3.

Month	Total catch (all species)	Total incidental catch	Salmonids[a] 1	Salmonids[a] 2	Salmonids[a] 3	Salmonids[a] L	Sturgeon 1	Sturgeon 2	Sturgeon 3	Sturgeon L	Bass 1	Bass 2	Bass 3	Catfish 1	Catfish 2	Catfish 3	Walleye 1	Walleye 2	Walleye 3	Shad	Other
COLUMBIA R.																					
May	58	8	0	0	0	1	0	0	0	0	5	0	0	0	0	0	0	0	0	1	1
June[b]	4217	242	1	0	0	2	14	2	0	25	102	0	0	52	0	12	0	0	0	12	20
July[b]	6796	222	1	0	0	0	15	0	0	22	146	0	0	16	0	0	2	0	0	11	9
August	5232	182	0	0	1	0	16	0	0	19	80	0	0	14	0	3	21	2	0	15	11
September	326	31	0	0	0	0	0	0	0	2	14	0	0	0	0	0	6	0	0	5	4
Season[b]	**16629**	**685**	**2**	**0**	**1**	**3**	**45**	**2**	**0**	**68**	**347**	**0**	**0**	**82**	**0**	**15**	**29**	**2**	**0**	**44**	**45**
SNAKE R.																					
May	25	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
June	310	54	0	0	0	0	3	0	0	1	10	0	0	20	0	20	0	0	0	0	0
July	613	123	0	0	0	0	2	0	0	4	9	0	0	93	0	14	0	0	0	0	1
August	344	122	0	0	0	0	1	0	0	1	6	0	0	85	0	29	0	0	0	0	0
September	14	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Season	**1306**	**301**	**0**	**0**	**0**	**0**	**6**	**0**	**0**	**7**	**25**	**0**	**0**	**199**	**0**	**63**	**0**	**0**	**0**	**0**	**1**
GRAND TOTAL																					
May	83	9	0	0	0	1	0	0	0	1	5	0	0	0	0	0	0	0	0	1	1
June[b]	4527	296	1	0	0	2	17	2	0	26	112	0	0	72	0	32	0	0	0	12	20
July[b]	7409	345	1	0	0	0	17	0	0	26	155	0	0	109	0	14	2	0	0	11	10
August	5576	304	0	0	1	0	17	0	0	20	86	0	0	99	0	32	21	2	0	15	11
September	340	32	0	0	0	0	0	0	0	2	14	0	0	1	0	0	6	0	0	5	4
Season[b]	**17935**	**986**	**2**	**0**	**1**	**3**	**51**	**2**	**0**	**75**	**372**	**0**	**0**	**281**	**0**	**78**	**29**	**2**	**0**	**44**	**46**

[a] Note that the 3 salmonids in conditions 1, 2, and 3 were juveniles, and the 3 in "L" (Lost) were adults.

[b] Does not include some data from John Day dam. See text for rationale. Excluded data are footnoted in Appendix Table D-1.13.

Appendix Table D-1.12. Monthly species composition of dam angling catch for **Columbia River** dams, 1993.

Month	Percent northern squawfish in total catch	Percent incidental species in total catch	Percent of total catch (all species)						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
BONNEVILLE									
May	88.89	11.11	0.00	0.00	7.41	0.00	0.00	3.70	0.00
June	99.21	0.79	0.00	0.43	0.00	0.00	0.00	0.36	0.00
July	99.34	0.66	0.00	0.25	0.04	0.00	0.00	0.37	0.00
August	98.09	1.91	0.00	0.88	0.07	0.00	0.00	0.89	0.07
September	76.32	23.68	0.00	0.00	5.26	0.00	0.00	13.16	5.26
Season	**98.80**	**1.20**	**0.00**	**0.46**	**0.10**	**0.00**	**0.00**	**0.59**	**0.05**
THE DALLES									
May	83.87	16.13	3.23	0.00	9.68	0.00	0.00	0.00	3.22
June	87.55	12.45	0.25	0.91	8.22	1.41	0.00	0.33	1.33
July	82.76	17.24	0.00	1.29	14.66	0.43	0.21	0.00	0.65
August	88.90	11.10	0.00	0.33	7.99	0.44	1.78	0.00	0.56
September	78.48	21.52	0.00	0.00	15.19	0.00	5.06	0.00	1.27
Season	**86.26**	**13.74**	**0.13**	**0.83**	**10.24**	**0.79**	**0.70**	**0.13**	**0.92**
JOHN DAY									
June	66.67	33.33	0.00	0.00	8.33	0.00	0.00	16.67	8.33
July	97.55	2.45	0.00	0.68	1.23	0.54	0.00	0.00	0.00
August	98.98	1.02	0.00	0.07	0.29	0.00	0.44	0.00	0.22
September	97.70	2.30	0.00	1.15	0.00	0.00	1.15	0.00	0.00
Season	**98.25**	**1.75**	**0.00**	**0.35**	**0.61**	**0.18**	**0.35**	**0.09**	**0.17**
McNARY									
June	94.44	5.56	0.00	1.71	0.15	3.48	0.00	0.00	0.22
July	98.92	1.08	0.04	0.54	0.00	0.33	0.00	0.04	0.12
August	97.33	2.67	0.07	1.20	0.20	0.87	0.07	0.13	0.13
September	97.14	2.86	0.00	0.00	0.00	0.00	0.00	0.00	2.86
Season	**97.32**	**2.68**	**0.04**	**1.02**	**0.09**	**1.28**	**0.02**	**0.06**	**0.17**

Appendix Table D-1.13. Monthly catch of incidental species by condition at release for Columbia River dams, 1993. Condition codes: 1) minimal injury, certain to survive; 2) moderate injury, may or may not survive; 3) dead, nearly dead, or certain to die; L) line cut or broken, fish not removed from the water. Catfish sacrificed for diet samples are included as condition 3.

Month	Total catch (all species)	Total incidental catch	Salmonids 1	Salmonids 2	Salmonids 3	Salmonids L	Sturgeon 1	Sturgeon 2	Sturgeon 3	Sturgeon L	Bass 1	Bass 2	Bass 3	Catfish 1	Catfish 2	Catfish 3	Walleye 1	Walleye 2	Walleye 3	Shad	Other
BONNEVILLE																					
May	27	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0
June	1652	13	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	6	0
July	2726	18	0	0	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0	10	0
August	1464	28	0	0	0	0	9	0	0	4	1	0	0	0	0	0	0	0	0	13	1
September	38	9	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	5	2
Total	**5907**	**71**	**0**	**0**	**0**	**0**	**9**	**0**	**0**	**18**	**6**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**35**	**3**
THE DALLES																					
May	31	5	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1
June	1205	150	1	0	0	2	2	0	0	9	99	0	0	17	0	0	0	0	0	4	6
July	928	160	0	0	0	0	5	0	0	7	136	0	0	4	0	0	2	0	0	0	6
August	901	100	0	0	0	0	0	0	0	3	72	0	0	4	0	0	16	0	0	0	5
September	79	17	0	0	0	0	0	0	0	0	12	0	0	0	0	0	4	0	0	0	1
Total	**3144**	**432**	**1**	**0**	**0**	**3**	**7**	**0**	**0**	**19**	**322**	**0**	**0**	**25**	**0**	**0**	**22**	**0**	**0**	**4**	**29**
JOHN DAY																					
June[a]	12	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1
July[b]	734	18	0	0	0	0	3	0	0	2	9	0	0	4	0	0	0	0	0	0	0
August	1368	14	0	0	0	0	0	0	0	1	4	0	0	0	0	0	4	2	0	0	3
September	174	4	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0
Total	**2288**	**40**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**5**	**14**	**0**	**0**	**4**	**0**	**0**	**6**	**2**	**0**	**2**	**4**
McNARY																					
June	1348	75	0	0	0	0	12	2	0	9	2	0	0	35	0	12	0	0	0	0	3
July	2408	26	1	0	0	0	7	0	0	6	0	0	0	8	0	0	0	0	0	1	3
August	1499	40	0	0	1	0	7	0	0	11	3	0	0	10	0	3	1	0	0	2	2
September	35	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total	**5290**	**142**	**1**	**0**	**1**	**0**	**26**	**2**	**0**	**26**	**5**	**0**	**0**	**53**	**0**	**15**	**1**	**0**	**0**	**3**	**9**

[a] Does not include 8 sturgeon (condition 1), 14 bass (condition 1), 10 catfish (condition 1), 11 shad, and 3 other. See text for rationale.

[b] Does not include 2 sturgeon (condition 1), 8 bass (condition 1), 1 walleye (condition 1), and 2 shad. See text for rationale.

Appendix Table D-1.14. Monthly species composition of dam angling catch for **Snake River** dams, 1993.

Month	Percent northern squawfish in total catch	Percent incidental species in total catch	Percent of total catch (all species)						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
ICE HARBOR									
June	32.26	67.74	0.00	9.68	9.68	48.38	0.00	0.00	0.00
July	39.61	60.39	0.00	1.30	1.30	57.79	0.00	0.00	0.00
August	57.95	42.05	0.00	1.14	3.41	37.50	0.00	0.00	0.00
Season	**44.69**	**5[illegible].31**	0.00	**2.20**	**2.93**	**50.18**	**0.00**	**0.00**	**0.00**
LOWER MONUMENTAL									
July	80.00	20.00	0.00	0.00	5.33	13.33	0.00	0.00	1.33
August	36.59	63.41	0.00	0.81	1.63	60.98	0.00	0.00	0.00
Season	**53.03**	**46.97**	**0.00**	**0.50**	**3.03**	**42.93**	**0.00**	**0.00**	**0.51**
LITTLE GOOSE									
May	75.00	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00
June	85.33	14.67	0.00	0.00	9.34	5.33	0.00	0.00	0.00
July	92.86	7.14	0.00	0.00	0.00	7.14	0.00	0.00	0.00
August	78.95	21.05	0.00	0.00	5.26	15.79	0.00	0.00	0.00
September	83.33	16.67	0.00	0.00	0.00	16.67	0.00	0.00	0.00
Season	[illegible]	**15.25**	**0.00**	**0.85**	**6.78**	**7.62**	**0.00**	**0.00**	**0.00**
LOWER GRANITE									
May	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June	89.22	10.78	0.00	0.49	0.00	10.29	0.00	0.00	0.00
July	96.22	3.78	0.00	1.08	0.81	1.89	0.00	0.00	0.00
August	97.37	2.63	0.00	0.00	0.00	2.63	0.00	0.00	0.00
September	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Season	**94.56**	**5.44**	**0.00**	**0.70**	**0.42**	**4.32**	**0.00**	**0.00**	**0.00**

Appendix Table D-1.15. Monthly catch of incidental species by condition at release for Snake River dams, 1993. Condition codes: 1) minimal injury, certain to survive; 2) moderate injury, may or may not survive; 3) dead, nearly dead, or certain to die; L) line cut or broken, fish not removed from the water.

Month	Total catch (all species)	Total incidental catch	Salmonids 1	Salmonids 2	Salmonids 3	Salmonids L	Sturgeon 1	Sturgeon 2	Sturgeon 3	Sturgeon L	Bass 1	Bass 2	Bass 3	Catfish 1	Catfish 2	Catfish 3	Walleye 1	Walleye 2	Walleye 3	Shad	Other
ICE HARBOR																					
June	31	21	0	0	0	0	3	0	0	0	3	0	0	6	0	9	0	0	0	0	0
July	154	93	0	0	0	0	2	0	0	0	2	0	0	78	0	11	0	0	0	0	0
August	88	37	0	0	0	0	0	0	0	1	3	0	0	30	0	3	0	0	0	0	0
Total	**273**	**151**	**0**	**0**	**0**	**0**	**5**	**0**	**0**	**1**	**8**	**0**	0	**114**	**0**	**23**	**0**	**0**	0	0	0
LOWER MONUMENTAL																					
July	75	15	0	0	0	0	0	0	0	0	4	0	0	9	0	1	0	0	0	0	1
August	123	78	0	0	0	0	1	0	0	0	2	0	0	50	0	25	0	0	0	0	0
Total	**198**	**93**	**0**	0	**0**	0	**1**	**0**	**0**	**0**	**6**	**0**	**0**	**59**	**0**	**26**	**0**	**0**	**0**	**0**	**1**
LITTLE GOOSE																					
May	4	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
June	75	11	0	0	0	0	0	0	0	0	7	0	0	2	0	2	0	0	0	0	0
July	14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
August	19	4	0	0	0	0	0	0	0	0	1	0	0	2	0	1	0	0	0	0	0
September	6	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Total	**118**	**18**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**8**	**0**	**0**	**5**	**0**	**4**	**0**	**0**	**0**	**0**	0
LOWER GRANITE																					
May	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	204	22	0	0	0	0	0	0	0	1	0	0	0	12	0	9	0	0	0	0	0
July	370	14	0	0	0	0	0	0	0	4	3	0	0	6	0	1	0	0	0	0	0
August	114	3	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
September	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**717**	**39**	0	**0**	**0**	**0**	**0**	**0**	0	**5**	**3**	**0**	0	**21**	**0**	**10**	**0**	**0**	**0**	**0**	0

Appendix Table D-1.16. Diet data for channel catfish caught at **McNary Dam.**

	June	July	Aug.
N (containing food)	11(4)	0(0)	3(1)
Predator weight [g]:			
Mean	2501	--	1723
Range	840-5000	--	1300-2100
Predator length [mm FL]:			
Mean	548	--	504
Range	360670		445-545
Mean weight [g] of food	13.1	--	13.7
% weight composition":			
Fish	38.6		42.4
Crustacea	60.2		0
Mollusca	0		0
Insecta	0	--	0
Plants	0	--	1.0
Other	1.2		56.7
Fish [total numbers]:			
Salmonids (CWT)	1(0)	--	0(0)
Mean per catfish	0.09	--	0.00
Sculpin	2	--	0
Stickleback	0	--	0
Shad	0	--	0
Cyprinids	0	--	0
Unidentified	1	--	0

[a] Unidentifiable contents not included.

Appendix Table D-1.17. Diet data for channel catfish caught at **Ice Harbor Dam.**

	June	July	Aug.
N (containing food)	9(5)	9(2)	3(1)
Predator weight [g]:			
Mean	1233	1266	1130
Range	730-2500	700-2360	830-1500
Predator length [mm FL]:			
Mean	444	457	446
Range	390-550	375-550	413-478
Mean weight [g] of food	9.2	9.7	6.0
% weight composition[a]:			
Fish	20.2	41.0	100.0
Crustacea	79.5	59.0	0
Mollusca	0	0	0
Insecta	0	0	0
Plants	0.3	0	0
Other	0	0	0
Fish [total numbers]:			
Salmonids (CWT)	0(0)	1(0)	0(0)
Mean per catfish	0.00	0.11	0.00
Sculpin	0	0	0
Sticlcleback	0	0	0
Shad	0	0	0
C yprinids	0	0	0
Ictalurid (catfish)	0	1	0

[a] Unidentifiable contents not included.

Appendix Table D-1.18. Diet data for channel catfish caught at **Lower Monumental Dam.**

	June	July	Aug.
N (containing food)	0(0)	2(1)	23(5)
Predator weight [g]:		750[a]	
Mean	--		637
Range	--		290-1060
Predator length [mm FL]:		395'	
Mean	--		384
Range	--		310-465
Mean weight [g] of food	--	6.1	6.7
% weight composition[b]:			
Fish	--	100.0	0
Crustacea	--	0	26.7
Mollusca	--	0	0
Insecta		0	0
Plants	--	0	32.9
Other	--	0	40.4
Fish [total numbers]:			
Salmonids (CWT)	--	0(0)	0(0)
Mean per catfish	--	0.00	0.00
Sculpin	--	0	0
Stickleback	--	0	0
Shad	--	0	0
Cyprinids	--	0	0
Unidentified	--	0	1

[a] Biological data on one of the two fish caught.
[b] Unidentifiable contents not included.

Appendix Table D-1.19. Diet data for channel catfish caught at **Little Goose Dam.**

	June	July	Aug.
N (containing food)	1(0)	1(0)	1(0)
Predator weight [g]:	3445	1130	1290
Predator length [mm FL]:	608	460	468
Mean weight [g] of food	4.1	3.3	8.2
% weight composition[a]:			
Fish	0	0	0
Crustacea	0	0	0
Mollusca	0	0	0
Insecta	0	0	0
Plants	0	0	0
Other	0	0	0
Fish [total numbers]:			
Salmonids (CWT)	0(0)	0(0)	0(0)
Mean per catfish	0.00	0.00	0.00
Sculpin	0	0	0
Stickleback	0	0	0
Shad	0	0	0
Cyprinids	0	0	0
Unidentified	0	0	0

[a] Unidentifiable contents not included.

Appendix Table D-1.20. Diet data for channel catfish caught at Lower **Granite Dam.**

	June	July	Aug.
N (containing food)	8(7)	1(0)	0(0)
Predator weight [g]:		1960	
Mean	1228		--
Range	630-1590		--
Predator length [mm FL]:		432	
Mean	449		--
Range	395-494		
Mean weight [g] of food	20.6	2.7	--
% weight composition[a]:			
Fish	0	0	--
Crustacea	5.6	0	--
Mollusca	0	0	--
Insecta	0	0	--
Plants	80.8	0	--
Other	13.6	0	--
Fish [total numbers]:			
Salmonids (CWT)	0(0)	0(0)	--
Mean per catfish	0.00	0.00	--
Sculpin	0	0	--
Stickleback	0	0	--
Shad	0	0	--
Cyprinids	0	0	--
Unidentified	0	0	--

[a] Unidentifiable contents not included.

Appendix Table D-1.21. Diet data for northern squawfish (NSF) caught at Bonneville Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	30(13)	38(11)	49(15)	4(2)
Predator weight [g]:					
Mean	--	914	766	700	1049
Range	--	360-1480	380-1520	230-1400	920-1210
Predator length [mm FL]:					
Mean	--	412	398	395	466
Range	--	319-511	318-523	287-490	442-493
Mean weight [g] of food	--	10.6	10.0	8.2	7.8
% weight composition[a]:					
Fish	--	65.7	58.6	93.5	0
Crustacea	--	29.3	0	3.2	96.0
Mollusca	--	0	0	0	0
Insecta	--	0	0	0	0
Plants	--	0.6	0.8	0	4.0
Other	--	4.5	40.6	3.4	0
Fish [total numbers):					
Salmonids (CWT)	--	8(1)	8(0)	8(0)	0(0)
Mean per NSF	--	0.26	0.21	0.16	0.00
Sculpin	--	0	1	0	0
Stickleback	--	1	0	0	0
Shad	--	0	0	0	0
Cyprinids	--	0	0	0	0
Unidentified	--	0	0	1	0
Mean water temperature	--	16.6	19.0	21.0	20.2
Consumption index	--	0.84	0.69	0.89	0.00

[a] Unidentifiable contents not included.

Appendix Table D-1.22. Diet data for northern squawfish (NSF) caught at The Dalles Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	49(6)	40(42)	43(18)	9(3)
Predator weight [g]:					
Mean	--	1142	1047	975	982
Range	--	140-2150	410-2000	380-1310	720-1270
Predator length [mm FL):					
Mean	--	425	437	441	458
Range	--	240-529	324-539	338-487	396-505
Mean weight [g] of food	--	9.4	12.6	12.3	6.5
% weight composition[a]:					
Fish	--	51.7	63.6	89.3	0
Crustacea	--	10.3	9.5	1.5	0
Mollusca	--	0	0	0	0
Insecta	--	0	0	0	15.9
Plants	--	0	16.5	0.8	35.5
Other	--	38.0	10.4	8.5	48.6
Fish [total numbers]:					
Salmonids- (CWT)	--	5(0)	18(1)	6(0)	0(0)
Mean per NSF	--	0.10	0.45	0.14	0.00
Sculpin	--	0	1	0	0
Stickleback	--	0	0	0	0
Shad	--	0	0	9	0
Cyprinids	--	2	0	2	0
Unidentified	--	0	0	0	1
Mean water temperature	--	16.3	19.0	20.6	20.1
Consumption index	--	0.31	1.62	0.37	0.00

[a] Unidentifiable contents not included.

Appendix Table D-1.23. Diet data for northern squawfish (NSF) caught at John Day Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	6(2)	0(0)	50(16)	20(11)
Predator weight [g]:					
Mean	--	1067	--	911	819
Range	--	760-1540	--	560-1630	550-1305
Predator length [mm FL]:					
Mean	--	425	--	434	420
Range	--	351-506	--	359-515	352-492
Mean weight [g] of food	--	10.1	--	11.6	14.8
% weight composition[a]:					
Fish	--	17.3	--	89.3	95.7
Crustacea	--	0	--	0	3.9
Mollusca	--	0	--	0	0
Insecta	--	0	--	0	0
Plants	--	0	--	0.2	0
Other	--	82.7	--	10.5	0.4
Fish [total numbers]:					
Salmonids- (CWT)	--	3(1)	--	7(0)	1(0)
Mean per NSF	--	0.50	--	0.14	0.05
Sculpin	--	0	--	0	0
Stickleback	--	0	--	0	0
Shad	--	0	--	7	10
Cyprinids	--	0	--	0	0
Unidentified	--	0	--	0	0
Mean water temperature	--	16.2	18.6	20.8	19.7
Consumption index	--	1.44	--	0.38	0.29

[a] Unidentifiable contents not included.

Appendix Table D-1.24. Diet data for northern squawfish (NSF) caught at McNary Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	30(15)	20(9)	15(2)	4(2)
Predator weight [g]:					
Mean	--	1126	955	366	835
Range	--	260-1730	600-1260	105-930	620-1400
Predator length [mm FL]:					
Mean	--	433	433	293	415
Range	--	296-507	379-489	205-435	380-485
Mean weight [g] of food	--	11.2	16.7	4.5	11.6
% weight composition[a]:					
Fish	--	74.0	80.8	100.00	100.00
Crustacea	--	24.5	0	0	0
Mollusca	--	0	0	0	0
Insecta	--	1.5	0	0	0
Plants	--	0	0	0	0
Other	--	0	19.2	0	0
Fish [total numbers]:					
Salmonids (CWT)	--	12 (0)	7(1)	0(0)	0(0)
Mean per NSF	--	0.40	0.35	0.00	0.00
Sculpin	--	3	1	1	0
Stickleback	--	0	0	0	0
Shad	--	0	0	1	2
Cyprinids	--	0	0	0	0
Unidentified	--	0	0	0	0
Mean water temperature	--	15.6	18.5	20.7	20.2
Consumption index	--	1.04	1.02	0.00	0.00

[a] Unidentifiable contents not included.

Appendix Table D-1.25. Diet data for northern squawfish (NSF) caught at Ice Harbor Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	8(3)	12(2)	11(4)	0(0)
Predator weight [g]:					
Mean	--	1130	773	829	--
Range	--	550-1450	330-1100	350-1770	--
Predator length [mm FL]:					
Mean	--	451	401	418	--
Range	--	352-505	295-450	338-543	--
Mean weight [g] of food	--	14.0	7.2	12.8	--
% weight composition[a]:					
Fish	--	0	0	97.2	--
Crustacea	--	72.3	5.4	0	--
Mollusca	--	0	0	0	--
Insecta	--	0	0	0	--
Plants	--	27.7	94.6	2.8	--
Other	--	0	0	0	--
Fish [total numbers]:					
Salmonids (CWT)	--	0(0)	0(0)	0(0)	
Mean per NSF	--	0.00	0.00	0.00	--
Sculpin	--	0	0	0	--
Stickleback	--	0	0	0	--
Shad	--	0	0	4	--
Cyprinids	--	0	0	1	--
Unidentified	--	0	0	0	--
Mean water temperature	--	15.0	18.2	19.6	--
Consumption index	--	0.00	0.00	0.00	--

[a] Unidentifiable contents not included.

Appendix Table D-1.26. Diet data for northern squawfish (NSF) caught at **Lower Monumental Dam.**

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	0(0)	15(10)	21(6)	0(0)
Predator weight [g]:					
Mean	--	--	964	643	--
Range	--	--	445-1550	190-2000	--
Predator length [mm FL]:					
Mean	--	--	425	378	--
Range	--	--	347-483	285-540	--
Mean weight [g] of food	--	--	11.6	8.2	--
% weight composition[a]:					
Fish	--	--	87.0	87.9	--
Crustacea	--	--	0	0	--
Mollusca	--	--	0	0	--
Insecta	--	--	0	5.2	--
Plants	--	--	13.0	5.0	--
Other	--	--	0	1.8	--
Fish [total numbers]:					
Salmonids (CWT)	--	--	9(5)	1(0)	--
Mean per NSF	--	--	0.60	0.05	--
Sculpin	--	--	0	0	--
Stickleback	--	--	0	0	--
Shad	--	--	0	2	--
Cyprinids	--	--	0	1	--
Unidentified	--	--	0	0	--
Mean water temperature	--	--	17.4	19.9	--
Consumption index	--	--	1.74	0.20	--

[a] Unidentifiable contents not included.

Appendix Table D-1.27. Diet data for northern squawfish (NSF) caught at Little Goose Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	16(8)	4(2)	5(4)	0(0)
Predator weight [g]:					
Mean	--	436	491	593	--
Range	--	304-725	300-735	315-1120	--
Predator length [mm FL]:					
Mean	--	337	355	367	--
Range	--	295-410	320-400	311-425	--
Mean weight [g] of food	--	4.4	6.7	6.2	--
% weight composition[a]:					
Fish	--	5.2	0	0	--
Crustacea	--	38.1	0	36.4	--
Mollusca	--	0	0	0	--
Insecta	--	32.1	61.3	0	--
Plants	--	1.5	3.6	63.6	--
Other	--	23.1	35.1	0	--
Fish [total numbers]:					
Salmonids (CWT)	--	0(0)	0(0)	0(0)	--
Mean per NSF	--	0.00	0.00	0.00	--
Sculpin	--	0	0	0	--
Stickleback	--	0	0	0	--
Shad	--	0	0	0	--
Cyprinids	--	1	0	0	--
Unidentified	--	0	0	0	--
Mean water temperature	--	15.5	18.0	20.4	--
Consumption index	--	0.00	0.00	0.00	--

[a] Unidentifiable contents not included.

Appendix Table D-1.28. Diet data for northern squawfish (NSF) caught at Lower Granite Dam.

	May	June	July	Aug.	Sept.
N (containing food)	11(5)	24(6)	19(5)	5(1)	0(0)
Predator weight [g]:					
Mean	506	716	568	513	--
Range	300-1150	300-1710	280-1725	340-725	--
Predator length [mm FL]:					
Mean	349	382	369	357	--
Range	212-418	291-493	283-541	320-393	--
Mean weight [g] of food	6.9	7.9	4.9	3.2	--
% weight composition[a]:					
Fish	73.2	62.1	33.5	72.9	--
Crustacea	0	36.7	60.0	0	--
Mollusca	0	0	0	0	--
Insecta	26.8	0	0	0	--
Plants	0	1.2	0	0	--
Other	0	0	6.5	27.1	--
Fish [total numbers]:					--
Salmonids (CWT)	2(1)	1(0)	1(0)	0(0)	--
Mean per NSF	0.18	0.04	0.05	0.00	--
Sculpin	0	0	0	0	--
Stickleback	0	0	0	0	--
Shad	0	0	0	0	--
Cyprinids	0	0	0	0	--
Unidentified	0	0	2	0	--
Mean water temperature	12.0	14.6	16.6	19.3	--
Consumption index	0.37	0.10	0.39	0.00	--

[a] Unidentifiable contents not included.

Appendix Table D-1.29. Number of catfish in each age group captured from Snake River dams and McNary Dam.

Dam	*N*	Age 5+	6+	7-k	8+	9+	10+	11+	12+
McNary	6	1	1	0	1	3	0	0	0
Ice Harbor	22	2	2	8	5	2	0	3	0
Lower Monumental	25	0	3	12	6	2	1	2	1
Little Goose	3	0	0	2	0	1	0	0	0
Lower Granite	10	0	0	2	1	4	1	2	0
Totals		3	6	24	13	12	2	7	1

REPORT E

Removal of Predaceous Northern Squawfish Found near Hatchery Release Sites in Bonneville Pool: An Analysis of Changes in Catch Rates and Diet Associated with the Release of Hatchery-Reared Juvenile Salmonids

Prepared by

Ken Collis, Roy E. Beaty, Becky Ashe,
Blaine Parker, and Kathy McRae

Columbia River Inter-Tribal Fish Commission
729 NE Oregon, Suite 200, Portland, OR 97232

George Lee
Confederated Tribes and Bands of the Yakhna Indian Nation
P.O. Box 151, Toppenish, WA 98948

1993 Annual Report

CONTENTS

ACKNOWLEDGEMENTS

We thank Steve Parker from the Confederated Tribes and Bands of the Yakima Indian Nation (YIN) for the early development of the ideas behind this work. Invaluable assistance was provided in the field by Carl Settler and Mike George. Dave Ward, Mark Zimmerman, and Kent Anderson (ODFW) provided logistical support. Laboratory analysis was carried out by Jack McCormack, Jennifer Oatman, and Bob Samuels. We also thank the numerous volunteers who helped us throughout the field season.

We thank the following hatchery managers and staff for their cooperation and assistance: Jack Bodle and Jim Rockowski (Little White Salmon and Willard National Fish hatcheries), Ed LaMotte (Spring Creek National Fish Hatchery), and Bruce McLeod (Carson National Fish Hatchery). Curt Burley, Steve Olhausen, and Dave Wills (Lower Columbia River Fish Resource Office, U.S. Fish and Wildlife Service) provided release information and assistance reading coded-wire tags. Valuable comments on this report were made by Kent Anderson, Brad Crain, Jeff Fryer, Doug Hatch, Chris Knutsen, Matthew Schwartzberg, Dave Ward, and Mark Zimmerman.

ABSTRACT

Predator control activities that target areas where northern squawfish (*Ptychocheilus oregonensis*) congregate to feed on juvenile salmonids have the advantage of (1) removing large numbers of mostly predator-sized northern squawfish and (2) focusing management efforts on areas where predation rates are especially high. We investigated the distribution and predation activities of northern squawfish at three locations in Bonneville Pool where hatchery-reared juvenile salmonids were released. Catch rates of northern squawfish increased significantly after hatchery releases at all three locations. In addition, the timing and duration of elevated catch rates in the sampling locations appear to be closely related to the release date and subsequent residence time of the hatchery-released fish in the area. Northern squawfish caught after salmonid releases had a significantly higher frequency of occurrence and mean number of juvenile salmonids in their diet compared to fish caught before releases. Consumption indices, used as a relative measure of consumption rates, were also higher at each location after, as compared to before, release. Our results suggest that northern squawfish respond numerically and functionally to releases of hatchery-reared juvenile salmonids in the spring. Removal efforts that target feeding concentrations of northern squawfish near hatchery release points may be a viable management alternative for reducing juvenile salmonid mortality rates in the Columbia River Basin.

INTRODUCTION

Hydroelectric dams have drastically changed the ecosystems of the mainstem Columbia and Snake rivers by altering natural flow patterns, water temperatures, sediment loads, and overall water quality (see Orth and White 1993). These changes have adversely affected anadromous salmonids (*Oncorhynchus* spp.; Raymond 1968, 1969, 1979, 1988; Trefethen 1972; Ebel 1977; NPPC 1986; Rieman et al. 1991), while benefitting many picivorous fishes that feed on out-migrating juvenile salmonids (NMFS 1991a, 1991b; Poe et al. 1991).

Dams have transformed the once free-flowing lower Columbia and Snake rivers into a series of low-velocity reservoirs. This poses a number of significant problems for juvenile anadromous salmonids (Raymond 1968; Trefethen 1972), among which is the increased risk of predation. Juvenile salmonids, often injured or disoriented after passing a dam, make easy prey (Poe et al. 1991). Impoundments created by the dams increase the travel time of juveniles migrating to the ocean, prolonging their exposure to predators (Raymond 1968, 1969, 1979, 1988; Bentley and Raymond 1976). Mortality estimates of juvenile salmonids passing an individual dam and reservoir range from 15% to 45 % (Sims and Ossiander 1981; Raymond 1979), prompting fisheries managers to investigate the extent to which predation is the cause for these losses.

Predator-prey relations were investigated from 1982-1986 in John Day Reservoir to quantify the effect of predation on annual mortality rates of juvenile salmonids observed in that reservoir. Of the four predators of juvenile salmonids studied — northern squawfish (*Ptychocheilus oregonensis*), walleye (*Stizostedion vitreum*), channel catfish (*Ictalurus punctatus*), and smallmouth bass (*Micropterus dolomieui)* — northern squawfish accounted for 78% of juvenile mortality attributed to predation, estimated to be roughly 2 million fish/year (Reiman et al. 1991). Subsequent indexing efforts below Bonneville Dam and in the other reservoirs on the lower Columbia and Snake rivers suggest that the annual systemwide loss of juvenile salmonids to predation by northern squawfish could be as high as 15-20 million fish (Beamesderfer and Ward 1993). Furthermore, northern squawfish seem particularly well-adapted to the low-velocity microhabitats created by the dams built along the lower Columbia and Snake rivers (Beamesderfer 1983; Faler et al. 1988; Beamesderfer and Rieman 1991), and evidence suggests that their numbers are increasing (Kim et al. 1986; Beamesdefer and Rieman 1991).

In 1991, the Columbia River Northern Squaw&h Management Program (CRNSMP) was implemented to reduce predation by northern squawfish on outmigrating juvenile salmonids in the lower reaches of the Columbia and Snake rivers. The program goal is to sustain a 10-20% annual exploitation rate on predator-sized (≥ 275 mm total length) northern squawfish, which over several years may result in a 50% reduction in predation on juvenile salmonids (Rieman and Beamesderfer 1990). Removal efforts of the CRNSMP have included (1) a sport-reward program, which pays sport anglers $3 for every predator-sized northern squawfish turned in to check stations; (2) a dam-angling fishery, in which technicians use hook and line to remove northern squawfish from areas near dams where these predators concentrate; and (3) a commercial fishery, which previously used longlines and currently deploys Merwin traps to catch northern squawfish in areas away from dams. In total, these efforts have achieved an exploitation rate that is at the lower end of the targeted goal. Given the rate of decline of many salmonid stocks in the Columbia River Basin and the recent listing of some upriver runs under the Endangered Species Act, the CRNSMP must reach and sustain a greater exploitation rate of northern squawfish to produce the desired benefit (Beamesderfer and Ward 1993). We believe that only through continued development of innovative harvest methods, using the most current information available on northern squawfish behavior and ecology, will the program goal be attained.

Predation by northern squawfish on juvenile salmonids has been shown to be unevenly distributed in space and time (Beamesderfer and Rieman 1991; Poe et al. 1991; Petersen and DeAngelis 1992) and is likely to be directly related to spatial and temporal differences in prey density. During their spring and summer outmigrations, juvenile salmonids are often concentrated unnaturally near mainstem dams and hatchery release points on the lower Columbia and Snake rivers. Northern squawfish, a highly gregarious and opportunistic predator, appear to aggregate in these areas to feed on juvenile salmonids (Brown and Moyle 1981; Beamesderfer and Rieman 1991; Poe et al. 1991). An effective way to catch predator-sized northern squawfish and reduce predation on juvenile salmonids might be to target these areas at times when prey densities are high (i.e., below fish hatcheries following the release of juvenile salmonids).

Here we investigate an alternative harvest method, specifically, the removal of northern squawfish from areas where hatchery-reared juvenile salmonids are released in Bonneville Pool. The objectives of this work were to (1) determine whether northern squawfish concentrate and are vulnerable to capture near hatchery release points and, if so, (2) ascertain the cause(s) for these aggregations (e.g., feeding, spawning, etc.). We will use information gathered here to develop a more comprehensive plan for managing predacious-sized northern squawfish at similar locations on the lower Columbia and Snake rivers.

METHODS

In 1993, we sampled at three locations — Spring Creek, Drano Lake,-and Wind River — in Bonneville Pool (Figure E-l), an impoundment created by Bonneville Dam, the lower-most reservoir on the Columbia River. We fished small-meshed gill nets (8 ft deep x 150 ft long constructed from 25-ft panels with the repeating mesh size sequence: 2 in, 1 3/4 in, and 1 1/4 in bar measures) at sites within upstream and downstream transects at each location (Figure E-2). Sampling took place from late March through late May on dates before and after hatchery releases at Spring Creek National Fish Hatchery (NFH), Little White Salmon NFH, Willard NFH, and Carson NFH (Tables E-l and E-2; **see Sampling Design).**

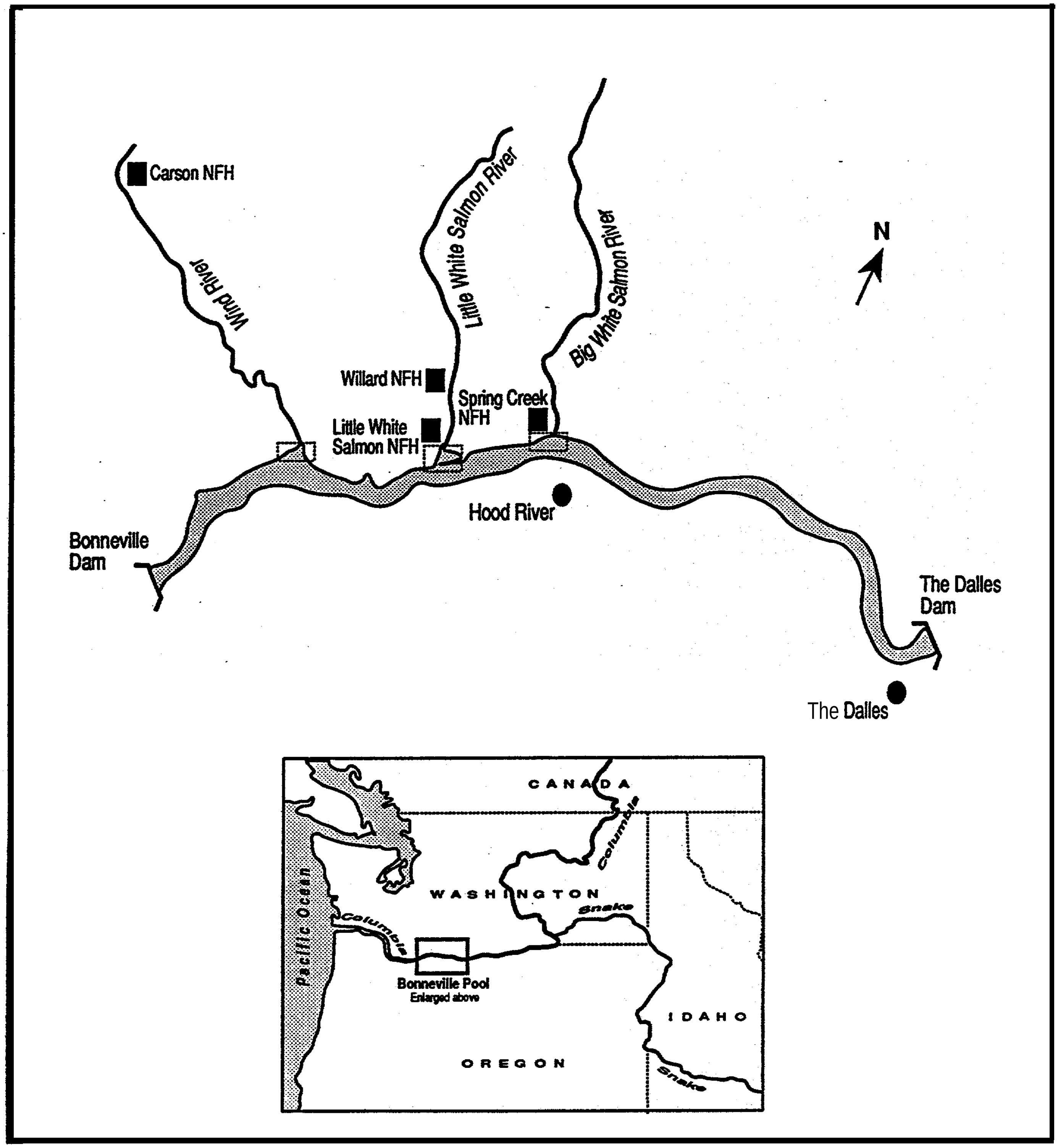


Figure E-l. Sampling locations (shown in dashed boxes) in Bonneville Pool, 1993. Locations (left to right: Wind River, Drano Lake, and Spring Creek) are shown in detail in Figure 2.

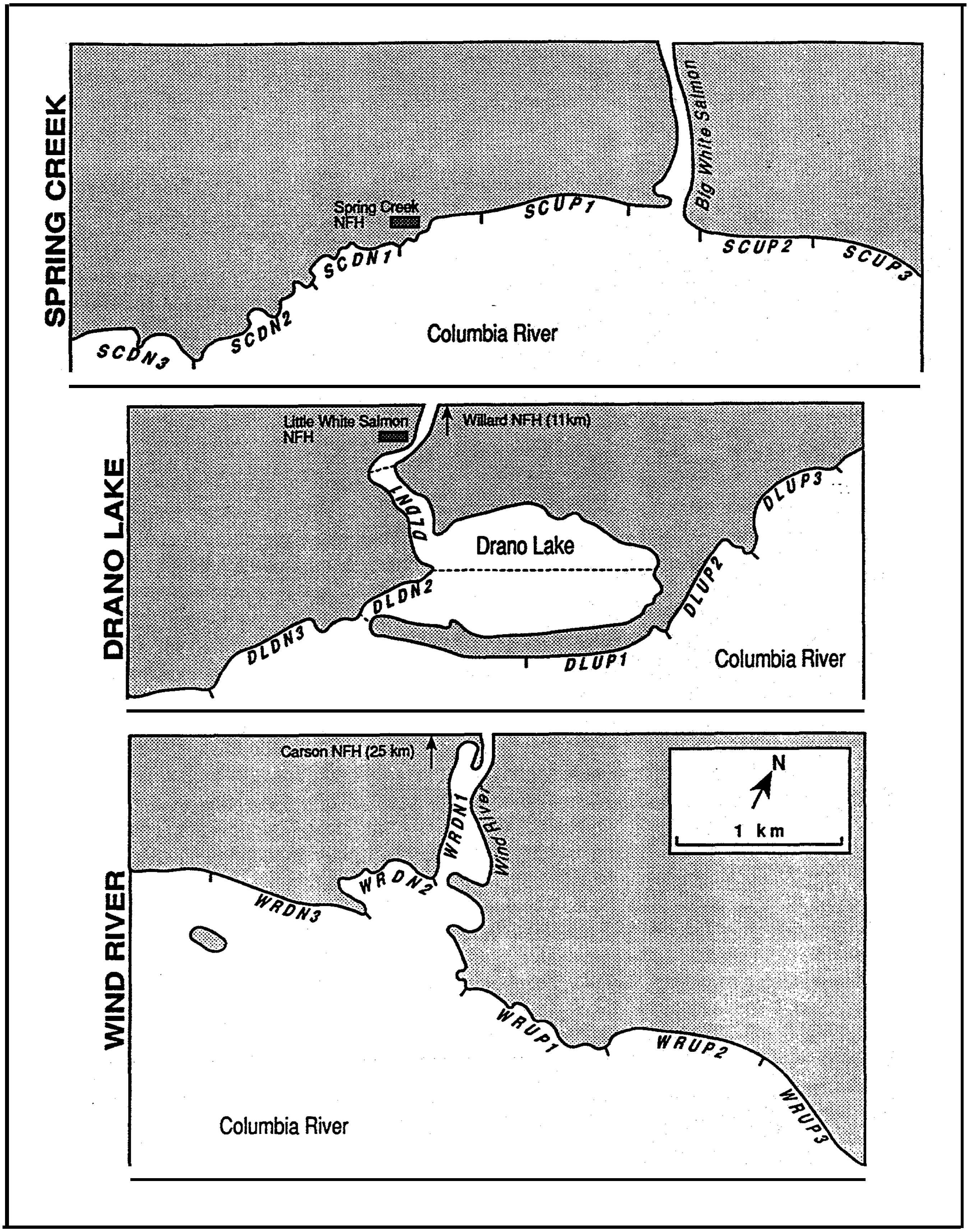


Figure E-2. Downstream (--DN-) and upstream (--UP-) transects at each sampling location in Bonneville Pool, 1993. A *site* is defined in this paper as a place within a transect where a net is fished.

Table E-1. Hatchery and sampling schedules and locations.

Hatchery	Release date	Sampling period (number of nights)		Location	
		Before release	After release	Release	Sampling
Spring Creek NFH	3/18	3/17 (1)	3/18 (1)	Columbia River at hatchery	Columbia River at hatchery
	4/15	4/12[a] (1)	4/15[b] (1)	Columbia River at hatchery	Columbia River at hatchery
	5/20	5/19 (1)	5/20 (1)	Columbia River at hatchery	Columbia River at hatchery
Little White Salmon & Willard NFH	4/15	3/25-4/13 (3)	4/16-5/25 (11)	Little White Salmon River	Drano Lake
Carson NFH	4/14	3/24-4/9 (2)	4/14-5/8 (6)	Wind River (25 km from mouth)	Wind River at mouth

[a] One sampling date (4/7) was removed from the before-release sampling group because juvenile salmonids released upstream were observed in large numbers in the sampling area.

[b] Four sampling dates (4/18, 4/21, 4/27, 5/4) were removed from the after-release sampling group because there was no evidence that hatchery fish released from Spring Creek NFH were still in the sampling area.

Table E2. Summary of spring releases of juvenile salmonids from Carson, Willard, Little White Salmon, and Spring Creek National Fish Hatcheries (NFH), 1993. Preliminary data (CRiS Database) provided by USFWS, Fishery Resources Office, Vancouver-, WA.

Hatchery/ release date	Species	Approx. size #/kg	Number released		
			Untagged	Tagged	TOTAL
Spring Creek NFH					
3/18/93	Chinook	308	6647,708	208,574	6,856,282
4/15/93	Chinook	212	3,143,388	835,476	3,978,864
5/20/93	Chinook	105	3,238,316	236,703	3,475,019
Little White Salmon NFH					
4/15/93	Chinook	40	781,804	27,275	809,079
Willard NFH					
4/15/93	Coho	40	3,013,690	49,925	3,063,615
Carson NFH					
4/14/93	Chinook	45	1,364,823	956,462	2,321,285

We enumerated the catch of each net and collected biological data on all northern squawfish caught, including fork length, weight, sex, and maturity (e.g., undeveloped, developing, ripe, or spawned). Subsequent data summaries and analyses include all northern squawfish caught, including those <250 mm, fork length **(see Data Analysis). Guts** collected from a randomly selected group of 5-10 northern squawfish $\cdot$ gill net^{-1} were frozen for later dietary analysis **(see Laboratory Analysis).** Species other than northern squawfish were identified to genus or species and immediately released back into the river. Incidentally caught game fish were assigned one of three condition codes at the time of release: (1) minimal injury, certain to survive; (2) moderate injury, may or may not survive; or (3) dead, nearly dead, or certain to die. Additionally, all salmonids caught were identified as either a juvenile or an adult and examined for external marks and/or fin clips. We also took detailed notes on the condition of each salmonid at release (i.e., was the fish bleeding, did the fish free itself from the net, how the fish was caught in the net?).

Each night we recorded information on weather and water conditions, including site-specific water temperatures. We also noted whether juvenile salmonids were observed in appreciable numbers ($>$ 100) in the water at each location (e.g., presence or absence). This was important because data not meeting assumptions regarding presence (expected after release) and absence (expected before release) of juvenile salmonids in the sampling area could be removed from statistical comparisons **(see Data Analysis** for further discussion).

Sampling Design

At each location, we fished small-meshed gill nets concurrently at upstream (1 net) and downstream (2 nets) transects before and after release (Table E-l; Figure E-2). The upstream transects were established as a control. We hypothesized that changes in both catch rate and diet of northern squawfish associated with hatchery release would occur only in transects downstream from the release point, since hatchery-released fish were expected to migrate downstream after release.

We sampled at night, placing most gill nets perpendicular to shore on the river bottom for approximately 1 hour. initially, we placed upstream and downstream nets in sites where northern squawfish were likely to concentrate based on the river conditions. Once we sampled a number of different sites, nets were placed in the most productive upstream and downstream sites and moved whenever catch rates fell below l-2 northern squawfish *gill net h^{-1}, or when ≥ 2 adult salmonids $\cdot$ gill net-' were caught. Locations were sampled at greater frequency immediately before and after the release dates and less frequently on dates more removed.

Laboratory Procedures

Diet analysis involved three major steps: (1) sorting and weighing gut contents, (2) digesting the soft gut contents, and (3) identifying and enumerating fish diagnostic bones. First, we squeezed the contents from thawed gut samples and sorted the items into seven categories: fish and fish parts, insects, crustaceans, mollusks, plant material, inorganic, and unidentified matter. Items in each category were blotted dry for approximately 60 seconds and then weighed to the nearest 0.1 g. If whole salmonids were present in the gut, they were counted, measured (fork length), and examined for fin clips. Once weighed, the voided gut and its contents were returned to its original sample bag for digestion.

The gut samples were then put through a digestion process according to the methods of Petersen et al. (1990, 1991) so that fish bones could be easily removed and identified. Any coded-wire tags detected in a sample were-removed using a magnetized rod and placed in a vial for later reading.

Finally, diagnostic bones (e.g., cleithra, dentaries, pharyngeal arches, and opercles) were identified and enumerated under a dissecting scope using a key developed by the U.S. Fish and Wildlife Service, Cook, Washington (unpub. data). When the number of prey fish consumed (based on paired diagnostic bones) differed from counts made during earlier sorting, we recorded the greater of the two numbers. Following enumeration, we preserved bones in 95% ethanol.

Data Analysis

We hypothesized that northern squawfish would show both a numerical and functional response to the release of hatchery fish in Bonneville Pool. A prediction of this hypothesis is that significant increases, from before to after release, in both catch rate and number of salmonids in the diet would be observed in downstream transects and not in the upstream transects where, presumably, hatchery-released fish would not be found. When assumptions about the presence or absence of juvenile salmonids in the sampling area were not met, those data were removed from all before-after comparisons and included in a supplemental sampling group. For example, at Spring Creek, where hatchery fish are released directly into the current of the mainstem Columbia River, smolts were observed in the sampling area only during the night following release in mid-April (4/15) and not thereafter. Consequently, nights sampled after 4/15 were excluded from before-after comparisons. Similarly, data from Spring Creek on 4/7 were removed from what would have been the before group because smolts released from an upstream hatchery were observed in large numbers in the sampling area.

Cl&squared and Fisher's exact test for independence were conducted using coded-wire tag recovery data at each location to determine whether the upstream transects served as a good control. We tested this hypothesis by comparing the following proportion, Coded-wire-tag (CWT) Recovery Index, between upstream and downstream transects:

$$\text{CWT Recovery Index} = \frac{\text{NSF w/CWT in gut}}{\text{NSF w/juvenile salmonids in gut}}$$

where: NSF = northern squawfish, and CWT = coded-wire-tagged juvenile salmonids released from the nearby hatchery. If the upstream sites were serving as a good control (i.e., catch rates unaffected by nearby hatchery release), then this proportion should be greater in downstream versus upstream transects.

Catch Data

We compared catch rate (northern squawfish . gill net h^{-1}; CPUE) before and after release at each location (unpaired student t-test); To separate the effects of hatchery release from other time- or site-related factors (e.g., water temperature, flow), we classified the data two ways: by time (before versus after release) and by site (upstream versus downstream from release point). The interaction term (time-by-site) in a two-way analysis of variance (ANOVA; Sokal and Rohlf 1981) was then used to analyze the effects of hatchery release on catch rate separate from other factors. We transformed catch data using $\log_{10}(x+1)$ to meet statistical assumptions (Moyle and Lound 1960; Elliott 1977; Beamesderfer and Rieman 1991). Catch data were also analyzed using likelihood ratio tests, which we present in **APPENDIX El.**

Diet Data

We investigated changes in the diet of northern squawfish associated with hatchery release at each location (functional response). We compared both the frequency of occurrence (chi-squared exact test for independence) and the mean number of salmonids (unpaired student t-test) recovered in the guts of northern squawfish caught before and after release. Counts of juvenile salmonids recovered in guts were transformed ($\sqrt{x+.5}$) to meet statistical assumptions (Sokal and Rohlf 1981). In addition, consumption indices (CI; see Petersen et al. 1990, 1991) were calculated to compare the relative consumption rates of juvenile salmonids by northern squawfish before and after hatchery release:

$$CI = 0.0209 \cdot T^{1.60} \cdot MW^{0.27} \cdot [MT_{sal} \cdot MGW^{-0.61}]$$

where: T = water temperature, MW = mean predator weight (g), MT, = mean number of salmonids/predator, and MGW = mean gut weight /predator (g). CI is not meant to be a rigorous measure of the number of salmonids consumed $\cdot$ predator^{-1} $\cdot$ day^{-1}.

At Spring Creek, we also investigated the relationship between the size of the hatchery fish released and the number and biomass of juvenile salmonids consumed by northern squawfish (Spearman rank correlation, Kruskal-Wallis H-test, Mann-Whitney U-test; see Siegel 1988).

RESULTS

From mid-March through mid-May 1993, 1,772 northern squawfish were caught in 394.4 net·h of effort at all locations, for a seasonal catch-per-unit-effort (CPUE) of 4.5. Of the total northern squawfish catch, 98.4% were "predator-size" (i.e., ≥250 mm, determined by the CRNSMP; Figure E-3). However, one of eight northern squawfish less than 250 mm (size range 238 mm - 249 mm) sampled for diet analysis contained juvenile salmonids, suggesting that the CRNSMP "predator-size" range may be conservative (see Thompson 1959; Falter 1969). Most (62.9%) were females, with the remainder classified as either male or immature (actual percentage unknown because some immature fish were misclassified as males). All mature fish were undergoing gonadal development and were not ripe. Seven fish that had been previously tagged ODFW and NMFS were recaptured (Table E-3).

Spring Creek

Catch Rate

The CPUE of northern squawfish was significantly higher (t = 2.56, P = 0.006) after releases of hatchery fish from Spring Creek NFH than before those releases (Table E-4). The distribution of CPUE over time showed peaks in catch rate associated with hatchery releases in April and May at downstream sites, whereas catch rates at upstream sites remained relatively constant (Figure E-4).

The time-by-site interaction in a two-way ANOVA was not significant (Table E-5). One possible explanation for this result is that the upstream sites were not removed far enough from the downstream sites to serve as good controls (see Figure E-2). In downstream and upstream transects, respectively, 6/33 and O/l 1 northern squawfish had CWT fish in their guts, which was not a statistically significant difference (Fisher's exact test, P = 0.16).

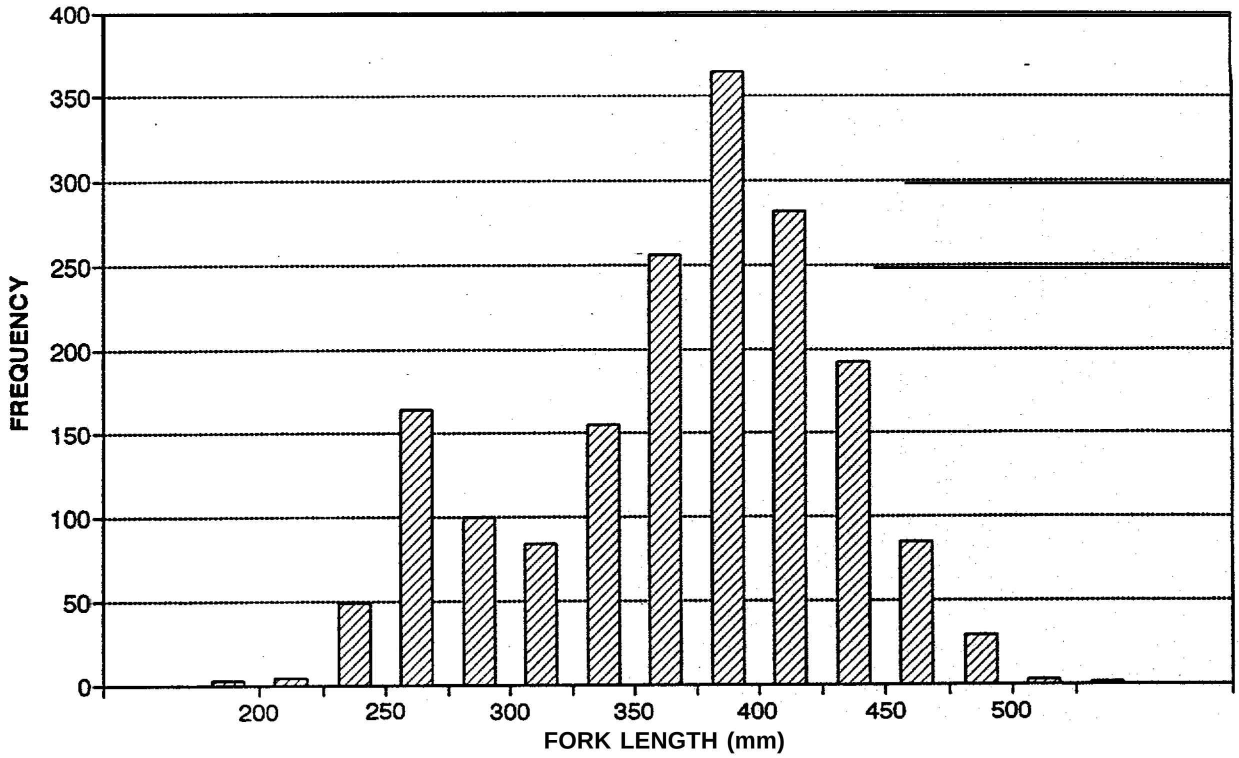


Figure E-3. **Size distribution of northern squawfish caught at all sampling locations in 1993.**

Table E-3. Northern squawfish recapture data at all locations sampled in 1993. Tagging information was provided by Dave Ward (ODFW, Clackamas, OR) and Bruce Monk (NMFS, Bonneville Field Station, WA).

Tagging information		Recapture information		
Date	Location (river km)	Date	Location (river km)	Distance from tagging location in river km
7/08/89	Bonneville Dam forebay (235)	4/28/93	Drano Lake (261	26
7/08/89	Bonneville Dam forebay (235)	5/07/93	Drano Lake (261)	26
7/25/91	Bonneville Dam forebay (235)	5/13/93	Drano Lake (261)	26
4/06/93	Below Spring Creek NFH (267)	4/15/93	Spring Creek (269)	2
4/06/93	Above Spring Creek NFH (271)	4/18/93	Spring Creek (269)	2
4/08/93	Mouth of Klickitat River (290)	4/22/93	Drano Lake (261)	29
4/29/93	Mouth of Wind River (250)	4/29/93	Wind River (248)	2
				$\bar{X} = 16.1$

Diet Analysis

Fish composed a greater proportion of the diet of northern squawfish caught after release compared to those caught before release (Figure E-5 and Table E-6). -Furthermore, the frequency of occurrence of juvenile salmonids in northern squawfish guts was significantly higher ($X^2 = 16.69$, $P < 0.0001$) after, as compared to before, release, as was the mean number of salmonids in the diet of all northern squawfish sampled ($t = 3.93$, $P <$ 0.0001). The consumption index for fish caught after release was higher than before release (Table E-6). The mean number of salmonids in the guts of northern squawfish caught in downstream transects peaked on dates following releases at Spring Creek NFH, whereas the corresponding measure in upstream transects showed no obvious pattern relative to release dates (Figure E-6).

In 1993, Spring Creek NFH had three separate releases, each differing in the average size of the juvenile salmonids released (Table E-2). The size of hatchery fish released (e.g., small, medium, and large based on the average size, see Table E-7) was negatively and significantly correlated ($r = -0.23$, $N = 78$, P c 0.0001) with the number of salmonid prey found in the guts of northern squawfish caught on the nights following each release. The biomass of juvenile salmonids *predator-' was also significantly and negatively correlated ($r = -0.17$, $N = 78$, $P = 0.0002$) with the size of the hatchery fish released. (Biomass is estimated as the number of juvenile salmonids in the guts of northern squawfish ÷ the average $\#\cdot kg^{-1}$ of. the hatchery fish released.) Mean comparisons showed significant differences in the biomass of juvenile salmonids consumed by northern squawfish based on average size of hatchery fish released (Table E-7). We assume in these comparisons that differences in the numbers of fish released (see Table E-2) need not be taken into account. These tests include only data from the first night after release (i.e., less than 12 h from the median release and sample times) when prey densities are likely to be sufficiently high that foraging success of northern squawfish probably is not dependent on the total number of fish released.

Table E-4. Northern squawfish gill-net catch and effort (net·h) at sites upstream and downstream from hatchery release points before and after release. The supplemental sampling group is excluded from all before-after comparisons.

		Upstream			Downstream			TOTAL		
Location		NSF[a]	Effort	CPUE	NSF[a]	Effort	CPUE	NSF[a]	Effort	CPUE
Spring Creek	Before:	25	11.0	2.3	46	25.7	1.8	71	36.7	1.9
	After:	32	10.6	3.0	113	29.9	3.8	145	40.5	3.6
	Supplemental:	92	25.3	3.6	91	41.7	2.2	183	67.0	2.7
Drano Lake	Before:	26	10.0	2.6	89	29.5	3.0	115	39.5	2.9
	After:	47	23.4	2.0	722	82.0	8.8	769	105.5	7.3
Wind River	Before:	13	5.6	2.3	67	21.1	3.2	80	26.7	3.0
	After:	136	26.9	5.0	273	51.6	5.3	409	78.5	5.2
TOTAL	Before:	64	26.6	2.4	202	76.3	2.6	266	102.9	2.6
	After:	215	60.9	3.5	1108	163.5	6.0	1323	224.5	5.9
	Supplemental:	92	25.3	3.6	91	41.7	2.2	183	67.0	2.7

[a] Includes northern squawfish (29) that were <250 mm.

Table E-5. Two-way **ANOVA** of northern squawfish CPUE for the three locations sampled in 1993.

Source of variation	df	*F*	*P*
Spring Creek			
Time (before vs. after)	1	4.63	0.03
Site (upstream vs. downstream)	1	0.21	0.22
Time-by-site	1	0.10	0.75
Drano Lake			
Time (before vs. after)	1	3.34	0.07
Site (upstream vs. downstream)	1	7.57	0.007
Time-by-site	1	3.50	0.06
Wind River			
Time (before vs. after)	1	6.11	0.01
Site (upstream vs. downstream)	1	0.00	0.98
Time-by-site	1	0.08	0.77

Table E-6. Comparisons of the diet of northern squawfish caught at each location before and after release.

		N[a]	% of diet (wet weight)				Salmonids in gut		CI[c]
			Fish	Crayfish	Plants	Other	%[b]	Mean ± SE	
Spring Creek	Before:	57	60.1	27.8	1.9	10.2	12.3	0.23 ± 0.10	0.24
	After:	78	93.1	4.7	0.4	1.8	50.0	2.55 ± 0.62	2.29
Drano Lake	Before:	66	35.2	22.9	4.6	37.3	6.1	0.14 ± 0.07	0.08
	After:	193	94.7	3.3	0.1	1.9	33.2	0.74 ± 0.10	0.69
Wind River	Before:	52	17.8	42.5	3.2	36.5	1.9	0.10 ± 0.10	0.05
	After:	117	93.1	6.0	0.1	0.8	30.8	0.55 ± 0.09	0.43
TOTAL	Before:	175	34.5	34.5	3.0	28.0	6.8	0.15 ± 0.05	0.11
	After:	388	94.0	4.3	0.2	1.5	35.8	1.04 ± 0.14	0.92

[a] Includes northern squawfish (9) that were <250 mm.
[b] Percent of northern squawfish with salmonids in gut.
[c] CI = consumption index.

Table E7. Differences (Kruskal-Wallis test, $H =$ 19.28, $P <$ 0.0001) in the number and biomass of juvenile salmonids consumed by northern squawfish feeding after the releases of small-, medium-, and large-sized juvenile salmonids. Means with different letters are significantly different (Mann-Whitney U-test, $P <$ 0.0001).

Release and sampling date	Size of released fish (#/kg)	N	Number of juvenile salmonids consumed Mean ± SE	Biomass of juvenile salmonids consumed (g) Mean ± SE
3/18/93	small (308/kg)	13	11.7 ± 2.5 *a*	37.9 ± 8.0 *a*
4/15/93	medium (212/kg)	46	0.9 ± 0.1 *b*	4.1 ± 0.7 *b*
5/20/93	large (105/kg)	19	0.4 ± 0.2 *b*	3.5 ± 1.7 *b*

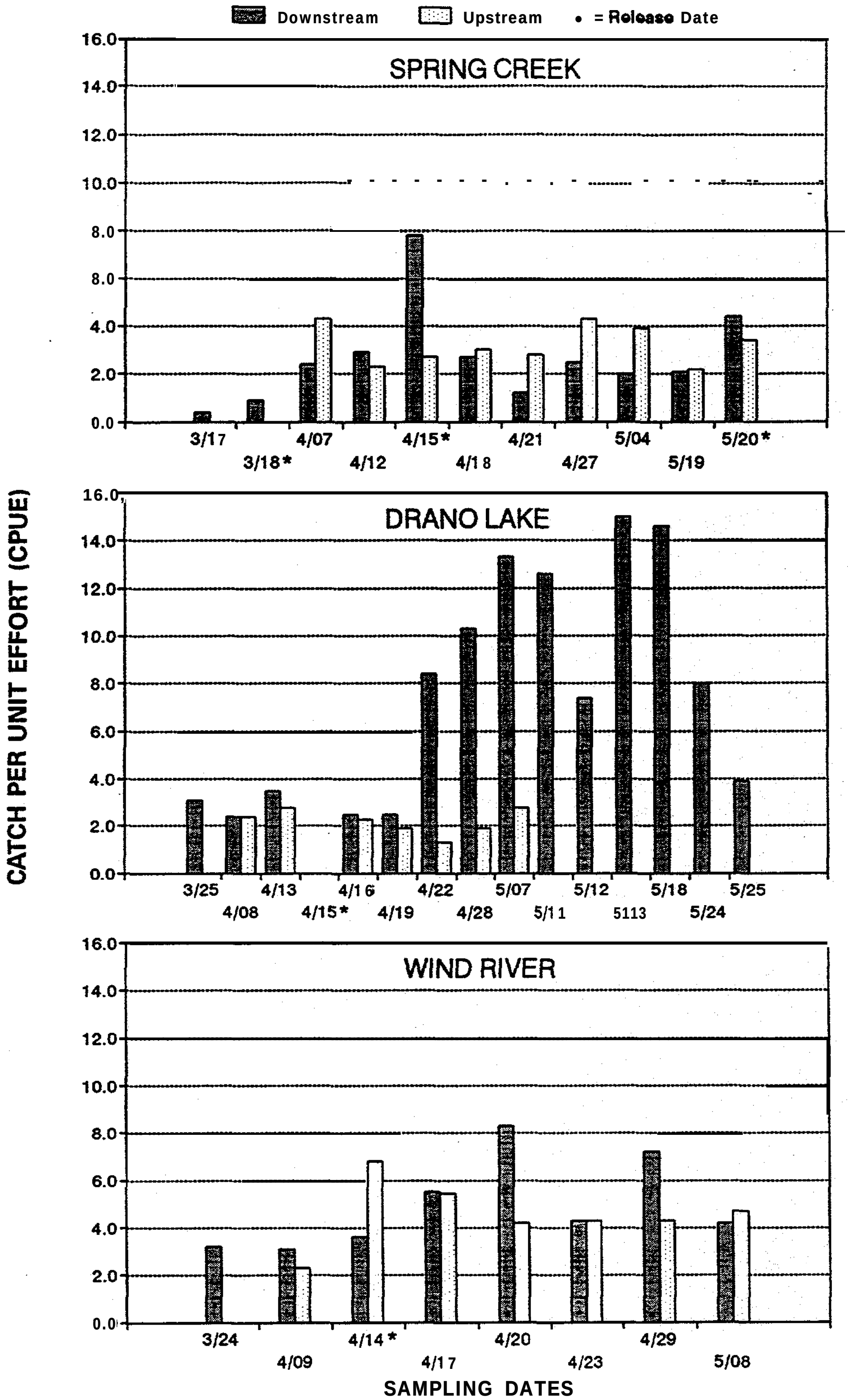


Figure E-4. CPUE of northern squawfish at down&ream and upstream transects on sampling dates before and after hatchery release. Upstream transects were not sampled before 4/7 at any location or after 5/7 at Drano Lake. Drano Lake was not sampled on 4/15.

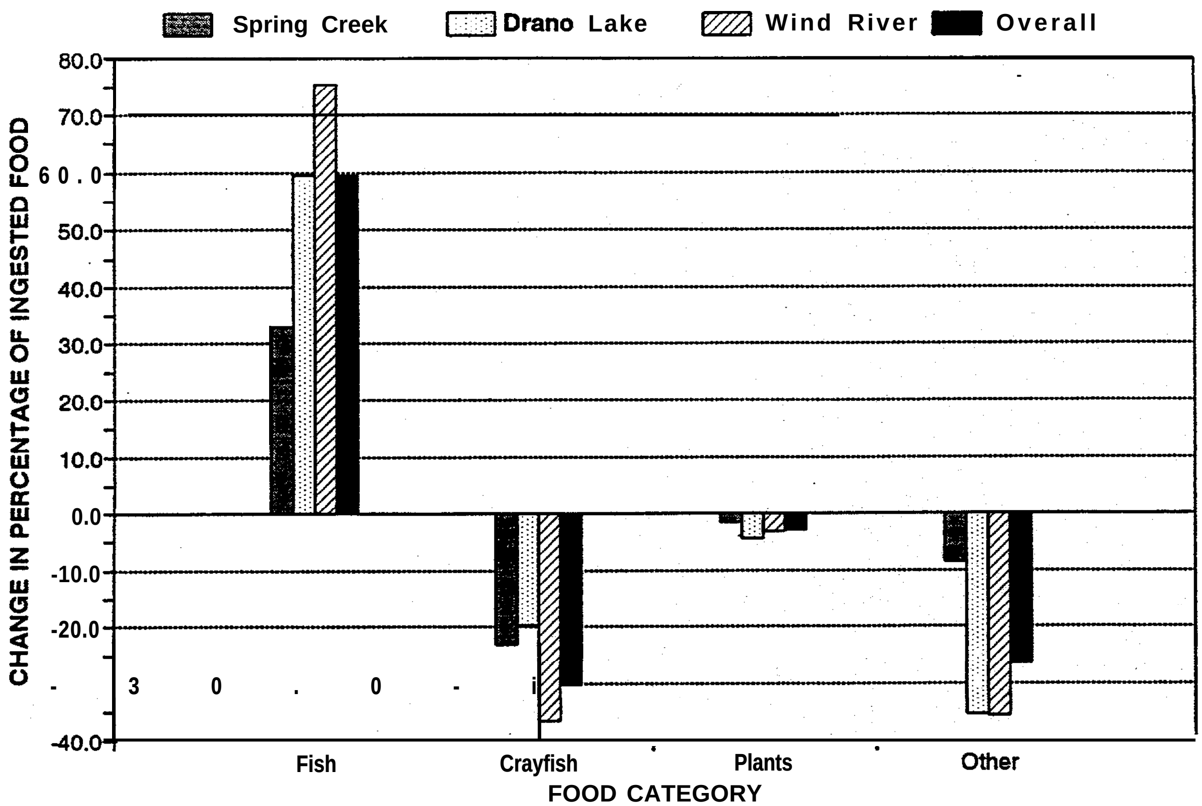


Figure E-5. Change (after release minus before release) of ingested food (% by weight) of northern squawfish caught at hatchery release sites. The "Other" category includes insects, mollusks, inorganic, and unidentified matter.

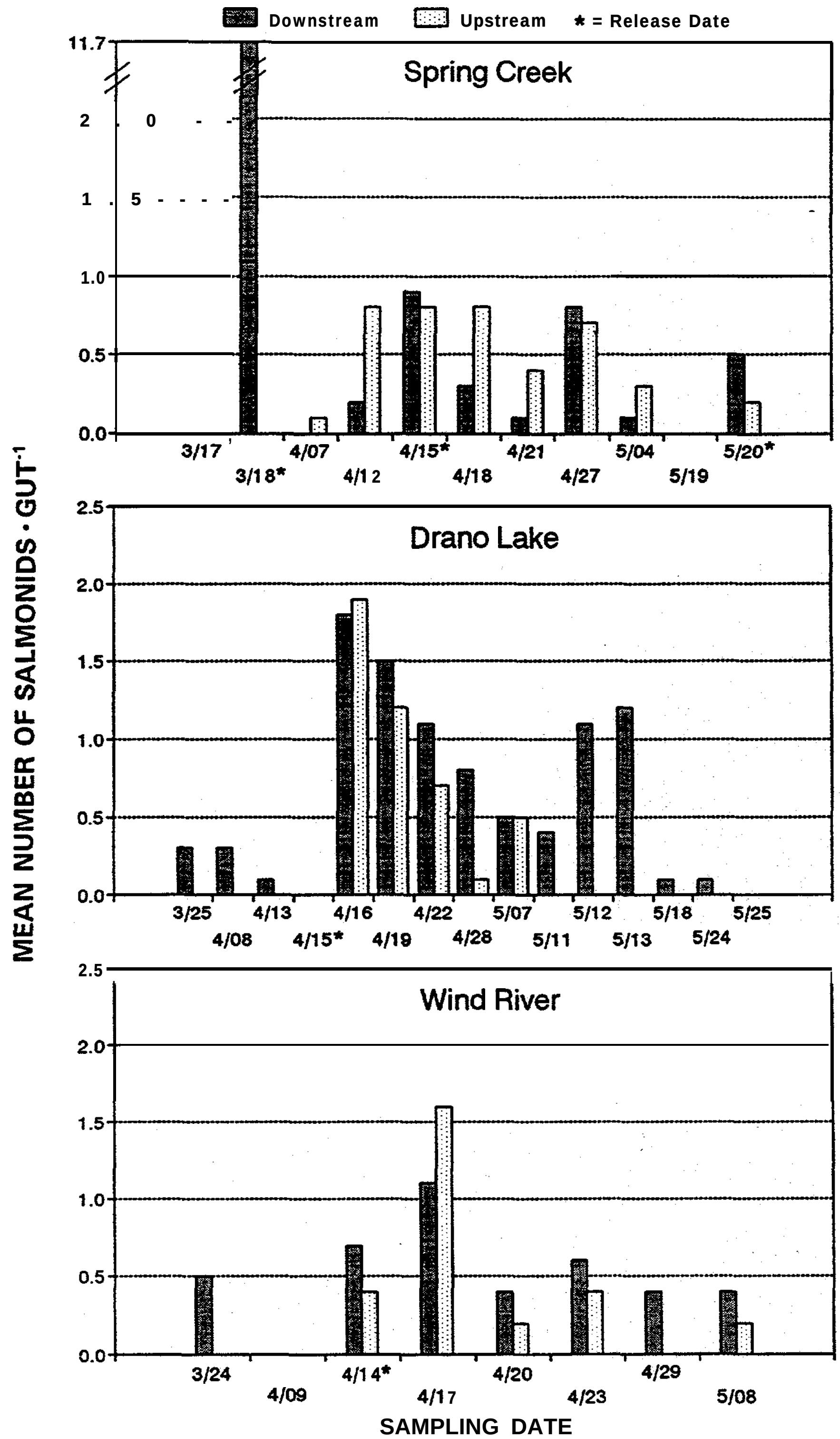


Figure E-6. Mean number of salmonids·gut^{-1} of northern squawfish caught at downstream and upstream transects on sampling dates before and after hatchery release. Upstream transects were not sampled before 4/7 at any location or after 5/7 at Drano Lake. Drano Lake was not sampled on 4/15. Please note different scales.

Drano Lake

Catch Rate

Northern squawfish CPUE was significantly higher (t = *3.30, P = 0.0006*) after, as compared to before, the release of hatchery fish into Drano Lake (Table E-4). Plots of CPUE at Drano Lake over time showed a dramatic increase in catch rates in downstream transects after hatchery releases, whereas CPUE in upstream transects was lower and remained relatively constant throughout the sampling period (Figure E-4). Furthermore, elevated catch rates in downstream sites were sustained for more than a month after hatchery release (Figure E-4). The time-by-site interaction was significant (Table E-5). We recovered only one coded-wire-tagged juvenile salmonid released from Little White Salmon and Willard NFHs in the guts of northern squawfish caught at Drano Lake. Consequently, a test to determine whether the upstream transects at Drano Lake served as a good control could not be conducted.

Diet Analysis

Fish and fish parts composed a greater proportion of the diet of northern squawfish after, as compared to before, hatchery releases (Figure E-5 and Table E-6). Also, a higher frequency of occurrence (X^2 = 18.70, $P < 0.0001$), mean number of juvenile salmonids in the diet (t = *3.65*, $P < 0.0004$), and consumption index were observed after, as compared to before, release (Table E-6). At Drano Lake, the mean number of juvenile salmonids in the diet of northern squawfish caught in both upstream and downstream transects increased on dates after release and remained above levels observed before release for nearly a month (Figure E-6).

Wind River

Catch Rate

Northern squawfish CPUE was significantly higher (t = 2.49, *P = 0.007*) at the mouth of the Wind River after the release of hatchery fish from Carson NFH as compared to before release (Table E-4). Plots of CPUE over time show increases immediately after release in both downstream and upstream sites (Figure E-4).

The time-by-site interaction in a two-way ANOVA was not significant (Table E-5). Comparisons of the proportions of northern squawfish caught in upstream and downstream transects having CWT fish released from Carson NFH in their guts (see CWT Recovery Index described above) indicate that the upstream sites were not far enough removed to be unaffected by the hatchery release (upstream: 12/21 NSF w/tagged fish in gut; downstream: 12/32 NSF w/tagged fish in gut, X^2 = 1.26, *P = 0.26*).

Diet Analysis

Fish composed a higher percentage of the gut contents of northern squawfish after release (compared to before release) at Wind River (Figure E-5 and Table E-6). Additionally, the frequency of occurrence of juvenile salmonids (X^2 = 16.69, $P < .0001$), mean number of juvenile salmonids (t = 3.93, $P < .0001$), and the consumption index were higher for northern squawfish caught after as compared to before release (Table E-6). The mean number of jwenile salmonids in the guts of northern squawfish caught on dates after release were higher than before release in both upstream and downstream transects (Figure E-6).

Incidental Catch

A total of 2,836 fish were incidentally caught at all locations sampled in 1993 (Table E-8). Salmonids composed 1.4% and 2.3% of the total and incidental catch, respectively, and most were released in good condition (Table E-9).

Table ES. Catches by species and location in 1993.

Species	Spring Creek	Drano Lake	Wind River	TOTAL
Northern squawfish *Ptychocheilus oregonensis*	399	884	489	1772
Incidental catch				
Peamouth *Mylocheilus caurinus*	327	521	849	1697
Largescale sucker *Catostomus macrocheilus*	302	236	282	820
White sturgeon *Acipenser transmontanus*	123	47	0	170
Salmonids[a] *Oncorhynchus spp.*	17	33	15	65
Chisehnouth *Acrocheilus alutaceus*	6	2	22	30
Bridgelip sucker *Catostomus coiumbianus*	15	12	1	28
Smalhnouth bass *Micropterus dokmiieui*	1	2	3	6
Brown bullhead *Ictalurus nebulosus*	1	3	1	5
Mountain whitefish *Prosopium williamsoni*	0	I	3	4
Yellow perch *Perca flavescens*	0	2	0	2
Redside shiner *Richardsonius balteatus*	1	1	0	2
Channel catfish *Ictalurus punctatus*	1	0	0	1
Largemouth bass *Micropterus sabnoides*	0	1	0	1
American shad *Alosa sapidissima*	1	0	0	1
Goldfish *Carassius auratus*	1	0	0	1
Sculpin *Cottus spp.*	0	1	0	1
Total incidental catch	796	862	1176	2834
TOTAL CATCH	1195	1746	1665	4606

[a] Salmonid catch is described in detail in Table 9.

Table E-9. Salmonid catch by location and condition at release in 1993. Condition codes: 1) minimal injury, certain to survive; 2) moderate injury, may or may not survive; 3) dead, nearly dead, or certain to die.

	Juvenile salmonids[a]			Adult salmonids		
Location	1	2	3	1	2	3
Spring Creek	6	2	1	6	2	0
Drano Lake	8	0	7	16	1	1
Wiid River	3	0	1	11	0	0
TOTAL	17	2[b]	9[b]	33[c]	3[d]	1[e]

[a] Not identified to species.
[b] Juvenile salmonids caught and released in Conditions 2 and 3 were just-released hatchery smolts that got their teeth tangled in the net.
[c] 18 chinook salmon, 12 steelhead, 2 chinook salmon (jack), 1 cutthroat trout.
[d] Steelhead.
[e] Chinook salmon (jack).

DISCUSSION

Catch rates of northern squawfish increased significantly following hatchery release at all three locations sampled, particularly on dates immediately following hatchery release. The duration of increased CPUEs appears to be closely related to the residence time of prey in the sampling area (see Management Implications). Furthermore, northern squawfish caught after release had a significantly higher frequency of occurrence and mean number of juvenile salmonids in their diet when compared to fish caught before release. Consumption indices used as a relative measure of consumption rates were also higher at each location after, as compared to before, release. These data are consistent with the hypothesis that northern squawfish immigrate into areas where hatchery-reared fish are released (numerical response) to feed on juvenile salmonids while they are concentrated (functional response; see Peter-man and Gatto 1978).

Other studies have suggested that northern squawfish are densely concentrated in areas where hatchery fish are released and that they are gathered there to feed. Shively et al. (1991) observed unusually high catch rates (for mid- and upper-reservoir locations) of northern squawfish at sites above Lower Granite Dam, which coincided with nearby hatchery releases. Consumption rates at one site in particular suggested that northern squawfish were there to feed on hatchery-released fish. In 1953, 3,425 northern squawfish were removed from Drano Lake using gill nets before, during, and after hatchery releases at Little White Salmon and Willard National Fish hatcheries (Zimmer 1953; USFWS 1957). Many of the northern squawfish caught were believed to have immigrated from the Columbia River into Drano Lake to feed on the hatchery-released fish. It was concluded, based on intensive sampling in the Columbia River from 1953-1956, that significant predation by northern squawfish occurred only at places where, and times when, hatchery-reared juvenile salmonids were released (USFWS 1957; Thompson 1959).

An alternative, but not mutually exclusive, hypothesis to explain increased catch rates following a hatchery release is that northern squawfish in the area feed more actively following a hatchery release and are therefore more susceptible to capture. A prediction of this hypothesis is that with intensive sampling, as was the case at Drano Lake in particular, one might expect the local population to be depleted over time. This prediction does not seem to be supported by our data. Plots of daily catch rate at Drano Lake remained high and relatively constant for more than a month after release (Figure E-4). Given the relatively small size of this sampling location and distances travelled by northern squawfish (Table E-3; Nigro et al. 1985) it is unlikely that increases in catch rates observed following release were not explained, at least in part, by northern squawfish immigrating into the sampling location from areas outside. In either case, these results support the hypothesis that northern squawfish are more easily caught in these areas after release, when hatchery fish are present in large numbers, than at other times or places that we sampled.

Limitations of Data

There is some evidence to suggest that the upstream transects were not good controls, as indicated by the non-significant time-by-site interactions in the two-way ANOVA's (Table E-5). First, the temporal changes (relative to release dates) in the mean number of salmonids in the guts of northern squawfish caught in downstream and upstream transects were similar at each location (Figure E-6). Furthermore, coded-wire tagged juvenile salmonids were recovered in the guts of northern squawfish caught in both upstream and downstream transects. Based on these data, the upstream transects may not have served as adequate controls (e.g., reference sites); therefore, we cannot rule out the possibility that the observed changes in catch rate and diet were due to other time-related factors such as changes in water temperature or flow.

The results at Drano Lake in particular need to be interpreted with some caution. Two downstream transects were located within the lake and all upstream transects were in the mainstem Columbia River. Therefore, dissimilarities in hydrology and other physical factors may have contributed to the observed differences in catch rate and diet between upstream and downstream transects. This may explain the significant site (upstream versus downstream) main effect in the two-way ANOVA (Table E-5). Also, a "hot spot" (i.e., site within a transect having high catch rates) was found after release that was not sampled before release, which may further influence those data. Nevertheless, we believe that in total our data provide convincing evidence of a functional response of northern squawfish to the release of hatchery fish and are consistent with the aggregation response hypothesis.

Management Implications

Important differences were observed between the three locations we sampled with respect to (1) river velocity, (2) residence time of hatchery-released fish at the sampling location, and (3) the size of the hatchery fish released. These differences and their effect on predation may be important to consider in management decisions aimed at reducing predation on juvenile salmonids, either by predator control or prey protection measures.

River velocities at the three sampling locations were dissimilar and probably influenced the residence times of juvenile salmonids released in these areas. Differences in residence time may explain the different patterns of predation activity observed at these locations. For example, hatchery fish released into Drano Lake, an embayment at the mouth of the Little White Salmon River formed by Bonneville Dam, were observed in abundance there more than a month after release. Conversely, hatchery fish from Spring Creek NFH were released into the main current of the Columbia River and were not observed in the sampling location after the first night following release. Plots of daily catch rates over time at Drano Lake and Spring Creek suggest a direct relationship between the abundance of juvenile salmonids and the abundance or catchability of northern squawfish in these areas (Figure E-4). Similarly, our data suggest that the mean number of juvenile salmonids in the diet of northern squawfish and prey abundance may be positively correlated, assuming prey abundance is greatest immediately following release and declines thereafter (Figure E-6). Based on these results, management activities aimed at reducing predation on juvenile salmonids should consider (1) removing predators from areas where residence times of juvenile salmonids are prolonged and (2) altering hatchery release strategies so that prey do not delay their outmigration and remain concentrated for long periods of time.

Our results suggest that there are significant differences in the predation activities of northern squawfish feeding on juvenile salmonids of different size. Spring Creek NFH had three separate hatchery releases, each differing in the average size of the juvenile salmonids released. We found a significant negative correlation between both the biomass and number of juvenile salmonids consumed by northern squawfish with the size category (e.g., small, medium, and large) of the fish released . Mean comparisons showed that northern squawfish caught after the release of small-sized hatchery fish had significantly greater biomass and numbers of juvenile salmonids in their diet as compared to those northern squawfish feeding on larger fish. There was no difference between the biomass and number of medium- and large-sized juvenile salmonids in the diet of northern squawfish feeding after these releases. These results suggest that, as far as point-source predation by northern squawfish is concerned, there may be an advantage to releasing larger fish. However, large fish (105 fish/kg) may not survive any better than medium-sized fish (212 fish/kg). These data indicate that predation risks faced by hatchery fish of different size should be considered along with other factors in hatchery production plans.

In summary, our data suggest that northern squawfish congregate near hatchery release sites in the spring to feed on juvenile salmonids. Removal efforts that target feeding concentrations of northern squawfish have the advantage of removing large numbers of mostly predator-sized northern squawfish from areas where predation rates are relatively high. Based on these data, predator control efforts targeting these and similar areas may be viable and important management alternatives for reducing juvenile salmonid mortality rates in the Columbia River Basin.

RECOMMENDATIONS

1. Expand the 1993 Bonneville Pool work to include additional sampling locations near hatchery release sites and other areas in the Columbia and Snake rivers where juvenile salmonids might concentrate. Site selection and sampling schedule should be dictated by hatchery release schedules and expected residence times of hatchery-released fish in the sampling location.

2. Use mobile Merwin traps along with small-meshed gill nets to target northern squawfish for removal. Merwin traps should be deployed when and where gill-net catches are high and incidental impacts are likely to be minimal. This integrated use

of sampling gears will result in added flexibility and probably increase efficiency and productivity over previous efforts utilizing these methods.

3. Coordinate with other agencies sampling on the Columbia and Snake rivers within season. Other agencies may identify other "hot spots" that we would not otherwise find. This coordination should also facilitate both project and program biological evaluation (e.g., estimation of exploitation rates, etc.).

4. Eliminate the smallest mesh panels (1 1/4" bar measure) in experimental gill nets. Medium and large-mesh (2" and 1 3/4" bar measure) are more effective in catching predator-sized northern squawfish (K. Collis, CRITFC, personal observation).

5. Continue to collect information on the spatial and temporal distribution, feeding habits, and general life history of northern squawfish. This information will help shape future removal efforts to become more cost-effective, as well as help hatchery managers determine hatchery release schedules and procedures.

6. Minimize potential impacts to salmonids by limiting sampling to late winter and spring months when water temperatures are lower and the abundance of adult salmonids, particularly listed stocks, are relatively low.

7. Continue to develop biologically sound operational criteria that will further minimize impacts to salmonids, particular listed stocks.

REFERENCES

Beamesderfer, R. C. 1983. Reproductive biology, early life history, and microhabitat of northern squawfish (*Ptychocheilus oregonensis*) in the St. Joe River, Idaho. Master Thesis. University of Idaho, Moscow.

Beamesderfer, R. C., and B. E. Rieman. 1991. Abundance and distribution of northern squawfish, walleye, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:439-447.

Beamesderfer, R. C., and D. Ward; 1993. An updated biological assessment of the Columbia River Squawfish Management Program. Draft manuscript dated July 1993. Oregon Department of Fish and Wildlife, Portland.

Bentley, W. W., and H. L. Raymond. 1976. Delayed migrations of yearling chinook salmon since completion of Lower Monumental and Little Goose dams on the Snake River. Transactions of the American Fisheries Society 105:422-424.

Brown, L. R., and P. B. Moyle. 1981. The impact of squawfish on salmonid populations: a review. North American Journal of Fisheries Management 1: 104-l 11.

Ebel, W. J. 1977. Major passage problems. American Fisheries Society Special Publication 10: 33-39.

Elliott, J. M. 1977. Some methods for the statistical analysis of samples of benthic invertebrates, 2nd edition. Freshwater Biological Association Scientific Publication **25.**

Faler, M. P., L. M. Miller, and K. I. Welke. 1988. Effects of variation in flow on distributions of northern squawfish in the Columbia River below McNary Dam. North American Journal of Fisheries Management 8:30-35.

Falter, C. M. 1969. Digestive rates and daily rations of northern squawfish in the St. Joe River, Idaho. Doctoral Dissertation. University of Idaho, Idaho.

Kim, R. A., R. D. Ledgerwood, and R. A. Nelson. 1986. Increased abundance and the food consumption of northern squawfish (*Ptychocheilus oregonensis*) at river kilometer 75 in the Columbia River. Northwest Science 60(3): 197-200.

Moyle, J. B., and R. Lound. 1960. Confidence limits associated with means and medians of series of net catches. Transactions of the American Fisheries Society 89:53-58.

Nigro, A., R. C. Beamesderfer, J. C. Elliot, M. P. Faler, L. M. Miller, B. L. Uremovich, and D. L. Ward. 1985. Abundance and distribution of walleye, northern squawfish, and smallmouth bass in John Day Reservoir, 1985. 1985 Annual Report. Contract DE-AI79-84BP35097, Bonneville Power Administration, Portland, Oregon.

NMFS (National Marine Fisheries Service). 1991a. Factors for decline, a supplement to the notice of determination for Snake River spring/summer chinook salmon under the Endangered Species Act. NMFS, Portland, Oregon.

NMFS (National Marine Fisheries Service). 1991b. Factors for decline, a supplement to the notice of determination for Snake River fall chinook salmon under the Endangered Species Act. NMFS, Portland, Oregon.

NPPC (Northwest Power Planning Council). 1986. Salmon and steelhead losses in the Columbia River Basin. NPPC, Portland, Oregon.

Orth, D. J., and R. J. White. 1993. Stream habitat management. Pages 205-230 *in C. C.* Kohler and W. A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Peterman, R. M., and M. Gatto. 1978. Estimation of functional responses of predators on juvenile salmon. Journal of the Fisheries Research Board of Canada 35:797-808.

Petersen, J. H., M. G. Mesa, J. Hall-Griswold, W. C. Schrader, G. W. Short, and T. P. Poe. 1990. Magnitude and dynamics of predators on juvenile salmonids in Columbia and Snake River reservoirs. Annual Report of Research, 1989-1990. Contract DE-AI79-88BP91964, Bonneville Power Administration, Portland, Oregon.

Petersen, J. H., D. B. Jepsen, R. D. Nelle, R. S. Shively, R. A. Tabor, and T. P. Poe. 1991. System-wide significance of predation on juvenile salmonids in Columbia and Snake River reservoirs. Annual Report of Research, 1990. Contract DE-AI79-90BP07096, Bonneville Power Administration, Portland, Oregon.

Petersen, J. H., and D. L. DeAngelis. 1992. Functional response and capture timing in an individual-based model: predation by northern squawfish (*Ptychocheilus oregonensis*) on juvenile salmonids in the Columbia River. Canadian Journal of Fisheries Aquatic Sciences 49:2551-2565.

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405-420.

Raymond, H. L. 1968. Migration rates of yearling chinook salmon in the Columbia River. Transactions of the American Fisheries Society 97:356-359.

Raymond, H. L. 1969. Effect of John Day Reservoir on the migration rate of juvenile chinook salmon in the Columbia River. Transactions of the American Fisheries Society 98:513-514.

Raymond, H. L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108: 505-529.

Raymond, H. L. 1988. Effects of hydroelectric development and fisheries enhancement on spring and summer chinook salmon and steelhead in the Columbia River Basin. North American Journal of Fisheries Management 8: l-24.

Rieman, B. E., and R. C. Beamesderfer. 1990. Dynamics of a northern squawfish population and the potential to reduce predation on juvenile salmonids in a Columbia River reservoir. North American Journal of Fisheries Management 10:228-241.

Rieman, B. E., R. C. Beamesderfer, S. Vigg, and T. P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleye, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:448-458.

Shively, R. S., R. A. Tabor, R. D. Nelle, D. B. Jepsen, J. H. Petersen, S. T. Sauter, and T. P. Poe. 1991. System-wide significance of predation on juvenile salmonids in Columbia and Snake River reservoirs. Annual Report of Research, 1991. Contract DE-AI79-90BP07096, Bonneville Power Administration, Portland, Oregon.

Siegel, S. 1988. Nonparametric statistics for the behavioral sciences. McGraw-Hill, New York.

Sims, C. W., and F. J. Ossiander. 1981. Migrations of juvenile chinook salmon and steelhead trout in the Snake River from 1973 to 1979. A research summary. Final Report. Contract DACW68-78-C-0038, U.S. Army Corps of Engineers, Portland, Oregon.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry, 2nd edition. W. H. Freeman, San Francisco.

Thompson, R. B. 1959. Food of the squawfish *Ptychocheilus oregonensis* (Richardson) of the lower Columbia River. U.S. Department of the Interior, Fish and Wildlife Service, Fishery Bulletin 158, Washington, D.C.

Trefethen, P. 1972. Man's impact on the Columbia River. Pages 77-98 *in* R.T. Oglesby, C. A. Carlson, and J. A. McCann, editors. River ecology and man. Academic Press, New York.

USFWS (United States Fish and Wildlife Service). 1957. Squawfish predation study. 1957 Progress Report. U.S. Fish and Wildlife Service, Portland, Oregon.

Zimmer, P. D. 1953. Observations on hatchery releases and squawfish predation in Little White Salmon River in spring of 1953. Processed Report. U.S. Fish and Wildlife Service, Portland, Oregon.

APPENDIX El

Liieliiood Ratio Test: An Alternative Method for Analyzing the Catch Data

Prepared by

Bradford R. Crain
Department of Mathematics
Portland State University
P.O. Box 751, Portland, OR **97207**

Introduction

This appendix contains an alternative statistical analysis of CPUE data **based on** the Poisson probability model. We use the abbreviations:

SCDNB = Spring Creek Downstream Before release
SCDNA = Spring Creek Downstream After release
SCUPB = Spring Creek Upstream Before release
SCUPA = Spring Creek Upstream After release

Similar abbreviations are used for Drano Lake data (DLDNB, DLDNA, DLUPB, DLUPA) and Wind River data (WRDNB, WRDNA, WRUPB, WRUPA).

Analysis of the Spring Creek Data

The Spring Creek CPUE data are summarized by the following array:

SCDNB	$n_1=23$	mean, = 1.550
SCDNA	$n_2=29$	$mean_2=3.728$
SCUPB	$n_3=11$	$mean_3=2.316$
SCUPA	$n_4=12$	$mean_4=3.227$

This array gives the individual sample sizes and sample means. The overall sample size and sample mean were $n=75$ and $mean=2.773$. We assume that we have sampled from four different Poisson populations with parameters $\lambda_1,\lambda_2,\lambda_3,\lambda_4$ respectively. Thus we assume that SCDNB data are Poisson(λ_1), SCDNA data are Poisson(&), SCUPB data are Poisson&), and SCUPA data are Poisson(&). This notation allows us to conveniently state various hypotheses of interest in terms of the parameters λ_i.

The first null hypothesis tested was that ail four Poisson populations are the same, versus the alternative hypothesis that they are not all the same. Symbolically, we test $H_o:\lambda_1=\lambda_2=\lambda_3=\lambda_4$ vs. $H_a:\lambda_i$'s not all equal. The method used was a likelihood ratio test, as described in Mathematical Statistics by Samuel S. Wilks (1962), John Wiley & Sons, New York. Essentially, the likelihood ratio test compares the maximum of the likelihood function of the data under the restriction H_o to the unrestricted maximum of the likelihood function. If we call this ratio A, then $-2\cdot\log(\Lambda)$ will be asymptotically chi-squared (all logarithms here are natural logarithms, or base e). The null hypothesis H_o is rejected when A is small, or equivalently when $-2\cdot\log(\Lambda)$ is large. The degrees of freedom is the loss of dimensionality in the $(\lambda_1,\lambda_2,\lambda_3,\lambda_4)$-space imposed by the restriction H,. In our first test, the loss of dimensionality is 4-l $=3$. The likelihood ratio test statistic (LRTS) turns out to be

$$LRTS = 2\sum_{i=1}^{4} n_i \overline{x}_i \log\left(\overline{x}_i / \overline{x}\right),$$

where $\bar{x}_i$ is an individual sample mean, and $\bar{\bar{x}}$s the overall sample mean.

The results of the test were:

$H_o:\lambda_1=\lambda_2=\lambda_3=\lambda_4$ vs. $H_a:\lambda_i$'s not all equal
LRTS = 25.0834
P-value = 0.0000

based on a chi-square distribution with 3 degrees of freedom. Thus H_o is rejected, and conclusion: the four populations are not the same.

The second null hypothesis tested is that there is no difference between Upstream and DowNstream sites. This hypothesis is stated as SCDNB=SCUPB and SCDNA=SCUPA. Equivalently, $H_o:\lambda_1=\lambda_3$ and $\lambda_2=\lambda_4$ vs. not H_o. The likelihood ratio test statistic is approximately chi-squared with 4-2=2 degrees of freedom. The actual form of the test statistic was:

$$LRTS = 2\cdot\left\{\sum_{i=1}^{4} n_i\bar{x}_i \log(\bar{x}_i) - (n_1\bar{x}_1+n_3\bar{x}_3)\log\left[\frac{n_1\bar{x}_1+n_3\bar{x}_3}{n_1+n_3}\right] - (n_2\bar{x}_2+n_4\bar{x}_4)\log\left[\frac{n_2\bar{x}_2+n\ \bar{x}_4}{n_2+n}\right]\right\}$$

The results of the test were:

$H_o:\lambda_1=\lambda_3$ and $\lambda_2=\lambda_4$ vs. not H_o
LRTS = 2.93613
P-value = 0.2304

based on a chi-square distribution with 4-2=2 degrees of freedom. Thus H_o is not rejected, and conclusion: Upstream is not significantly different than DowNstream.

The third null hypothesis tested is that there is no difference between Before and After data. This hypothesis is stated as SCDNB=SCDNA and SCUPB=SCUPA. Equivalently, $H_o:\lambda_1=\lambda_2$ and $\lambda_3=\lambda_4$ vs. not H,. The likelihood ratio test statistic is approximately chi-squared with 4-2=2 degrees of freedom.
The actual form of the test statistic was:

$$LRTS = 2\cdot\left\{\sum_{i=1}^{4} n_i\bar{x}_i \log(\bar{x}_i) - (n_1\bar{x}_1+n_2\bar{x}_2)\log\left[\frac{n_1\bar{x}_1+n_2\bar{x}_2}{n_1+n_2}\right] - (n_3\bar{x}_3+n_4\bar{x}_4)\log\left[\frac{n_3\bar{x}_3+n\ \bar{x}_4}{n_3+n}\right]\right\}$$

The results of the test were:

$H_o:\lambda_1=\lambda_2$ and $\lambda_3=\lambda_4$ vs. not H_o
LRTS = 25.3159
P-value = 0.0000

based on a chi-square distribution with 4-2=2 degrees of freedom. Thus H_o is not accepted, and conclusion: Before data and After data are significantly different.

The fourth null hypothesis tested is that the interaction between Before/After and DowNstream/UPstream is zero. This hypothesis is stated as SCDNB-SCDNA=SCUPB-SCUPA, or as SCDNB-SCDNA-SCUPB+SCUPA=O. Equivalently, this is expressed as $H_o:\lambda_1-\lambda_2-\lambda_3+\lambda_4=0$ vs. not H_o. The likelihood ratio test for this hypothesis could not be derived in closed form. A Z-test was substituted instead. The form of the test was:

$$Z\text{-}TEST = \frac{(\bar{x}_1-\bar{x}_2-\bar{x}_3+\bar{x}_4) - (0)}{\sqrt{\sum_{i=1}^{4}\left(\frac{\bar{x}_i}{n_i}\right)}}$$

The results of the test were:

$H_o:\lambda_1-\lambda_2-\lambda_3+\lambda_4=0$ vs. not H_o
Z-TEST = -1.54168
P-value = 0.1232

based on a standard normal (Z) distribution. Thus H_o is not rejected, and conclusion: the DowNstream/UPstream and Before/After interaction is not significant.

Analysis of the Drano Lake Data

The Drano Lake CPUE data is summarized by the following array:

DLDNB	n, =28	mean, =2.973
DLDNA	n_2=81	$mean_2$=8.830
DLUPB	n_3=10	$mean_3$=2.379
DLUPA	n_4=21	$mean_4$=2.085

This array gives the individual sample sizes and sample means. The overall sample size and sample mean were n=140 and mean=6.186. We assume that we have sampled from four different Poisson populations with parameters $\lambda_1,\lambda_2,\lambda_3,\lambda_4$ respectively. Thus we assume that DLDNB data are Poisson(λ_1), DLDNA data are Poisson@,), DLUPB data are Poisson(&), and DLUPA data are Poisson(λ_4). This notation allows us to state various hypotheses of interest in terms of the parameters λ_i.

The first null hypothesis tested was that all four Poisson populations are the same, versus the alternative hypothesis that they are not all the same. Symbolically, we test $H_o:\lambda_1=\lambda_2=\lambda_3=\lambda_4$ vs. $H_a:\lambda_i$'s not all equal. The likelihood ratio test statistic is the same as before.

The results of the test were:

$$H_o:\lambda_1=\lambda_2=\lambda_3=\lambda_4 \text{ vs. } H_a:\lambda_i\text{'s not all equal}$$
LRTS = 246.334
P-value = 0.0000

based on a chi-square distribution with 3 degrees of freedom. Thus H_o is rejected, and conclusion: the four oonulations are not the same.

The second null hvoothesis tested is that there is no difference between Upstream and DowNstream sites. This hypothesis is stated as DLDNB=DLUPB and DLDNA=DLUPA. Equivalently, $H_o:\lambda_1=\lambda_3$ and $\lambda_2=\lambda_4$ vs. not H_o. The likelihood ratio test **statistic** is approximately chi-squared with **4-2=2** degrees of freedom. The actual form of the test statistic is the same as before.

The results of the test were:

$$H_o:\lambda_1=\lambda_3 \text{ and } \lambda_2=\lambda_4 \text{ vs. not } H_o$$
LRTS = 134.304
P-value = 0.0000

based on a chi-square distribution with **4-2=2** degrees of freedom. Thus H_o is rejected, and conclusion: there exists a **significant** difference between Upstream and **DowNstream.**

The third null hvoothesis tested is that there is no difference between Before and After data. This hypothesis is stated as DLDNB=DLDNA and DLUPB=DLUPA. Equivalently, $H_o:\lambda_1=\lambda_2$ and $\lambda_3=\lambda_4$ vs. not H,. The likelihood ratio test statistic is approximately chi-squared with **4-2=2** degrees of freedom.
The actual form of the test statistic is the same as before.

The results of the test were:

$$H_o:\lambda_1=\lambda_2 \text{ and } \lambda_3=\lambda_4 \text{ vs. not } H_o$$
LRTS = 117.339
P-value = 0.0000

based on a chi-square distribution with **4-2=2** degrees of freedom. Thus H_o is rejected, and conclusion: Before data and After data are **significantlv** different.

The fourth null hvoothesis tested is that the interaction between Before/After and DowNstream/UPstream is zero. This hypothesis is stated as **DLDNB-DLDNA=DLUPB-**DLUPA, or as DLDNB-DLDNA-DLUPB+DLUPA=O. Equivalently, this is expressed as $H_o:\lambda_1-\lambda_2-\lambda_3+\lambda_4=0$ vs. not H_o. The form of the test was the same as before.

The results of the test were:

$$H_o{:}\lambda_1-\lambda_2-\lambda_3+\lambda_4=0 \text{ vs. not } H_o$$
Z-TEST = -8.27614
P-value = 0.0000

based on a standard normal (Z) distribution. Thus H_o is rejected, and conclusion: the DowNstream/UPstream and Before/After interaction is significant.

Analysis of the Wiid River Data

The Wind River CPUE data are summarized by the following array:

WRDNB	$n_1=18$	$mean_1=3.181$
WRDNA	$n_2=44$	$mean_2=5.210$
WRUPB	$n_3=5$	$mean_3=2.392$
WRUPA	$n_4=25$	$mean_4=5.085$

This array gives the individual sample sizes and sample means. The overall sample size and sample mean were n =92 and mean =4.626. We assume that we have sampled from four different Poisson populations with parameters $\lambda_1,\lambda_2,\lambda_3,\lambda_4$ respectively. Thus we assume that WRDNB data are Poisson&), WRDNA data are Poisson&), WRUPB data are Poisson@,), and WRUPA data are Poisson(λ_4). This notation allows us to state various hypotheses of interest in terms of the parameters λ_i.

The first null hvnothesis tested was that all four Poisson populations are the same, versus the alternative hvnothesis that thev are not all the same. Symbolically, we test $H_o{:}\lambda_1=\lambda_2=\lambda_3=\lambda_4$ vs. $H_a{:}\lambda_i$'s not all equal. The likelihood ratio test statistic is the same as before.

The results of the test were:

$$H_o{:}\lambda_1=\lambda_2=\lambda_3=\lambda_4 \text{ vs. } H_a{:}\lambda_i\text{'s not all equal}$$
LRTS = 19.8975
P-value = 0.0002

based on a chi-square distribution with 3 degrees of freedom. Thus H_o is rejected, and conclusion: the four populations are not the same.

The second null hvoothesis tested is that there is no difference between Upstream and DowNstream sites. This hypothesis is stated as WRDNB=WRUPB and WRDNA=WRUPA. Equivalently, $H_o{:}\lambda_1=\lambda_3$ and $\lambda_2=\lambda_4$ vs. not H_o. The likelihood ratio test statistic is approximately chi-squared with 4-2=2 degrees of freedom. The actual form of the test statistic is the same as before.

The results of the test were:

H_o:$\lambda_1=\lambda_3$ and $\lambda_2=\lambda_4$ vs. not H_o
LRTS = 0.902954
P-value = 0.6367

based on a chi-square distribution with 4-2=2 degrees of freedom. Thus H_o is not rejected, and conclusion: no significant difference between Upstream and DowNstream.

The third null hypothesis tested is that there is no difference between Before and After data. This hypothesis is stated as **WRDNB=WRDNA** and **WRUPB=WRUPA.** Equivalently, H_o:$\lambda_1=\lambda_2$ and $\lambda_3=\lambda_4$ vs. not H_o. The likelihood ratio test statistic is approximately chi-squared with 4-2=2 degrees of freedom.
The actual form of the test statistic is the same as before.

The results of the test were:

H_o:$\lambda_1=\lambda_2$ and $\lambda_3=\lambda_4$ vs. not H_o
LRTS = 19.9143
P-value = 0.0000

based on a chi-square distribution with 4-2=2 degrees of freedom. Thus H_o is rejected, and conclusion: Before data and After data are significantly different.

The fourth null hypothesis tested is that the interaction between Before/After and DowNstream/UPstream is zero. This hypothesis is stated as **WRDNB-WRDNA=WRUPB-**WRUPA, or as WRDNB-WRDNA-WRUPB+WRUPA=O. Equivalently, this is expressed as H_o:$\lambda_1-\lambda_2-\lambda_3+\lambda_4=0$ vs. not H,. The form of the test was the same as before.

The results of **the test were**:

H_o:$\lambda_1-\lambda_2-\lambda_3+\lambda_4=0$ vs. **not** H_o
Z-TEST = 0.671794
P-value = 0.5018

based on a standard normal (Z) distribution. Thus H_o is not rejected, and conclusion: the DowNstream/UPstream and Before/After interaction is not significant.

SPRING CREEK STATISTICAL CPUE DATA SUMMARY

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
SCDNB	23	1.550	1.000	1.353	1.921	0.401
SCDNA	29	3.728	2.410	3.414	4.216	0.783
SCUPB	11	2.316	3.000	2.236	1.912	0.576
SCUPA	12	3.227	2.955	3.175	1.854	0.535
ALL	75	2.773	1.820	2.388	3.117	0.360

	MIN	MAX	Q1	Q3
SCDNB	0.000	7.230	0.000	2.680
SCDNA	0.000	15.930	0.455	5.925
SCUPB	0.000	5.360	0.000	3.660
SCUPA	0.820	6.150	1.388	5.155
ALL	0.000	15.930	0.000	4.000

DRANO LAKE STATISTICAL CPUE DATA SUMMARY

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
DLDNB	28	2.973	2.860	2.823	2.210	0.418
DLDNA	81	8.83	6.25	7.84	9.03	1.00
DLUPB	10	2.379	2.220	2.245	1.866	0.590
DLUPA	21	2.085	2.000	2.094	1.172	0.256
ALL	140	6.186	3.880	5.148	7.621	0.644

	MIN	MAX	Q1	Q3
DLDNB	0.000	9.820	1.385	4.345
DLDNA	0.00	47.86	2.37	12.24
DLUPB	0.000	5.830	0.728	4.000
DLUPA	0.000	4.000	1.275	3.115
ALL	0.000	47.860	1.653	8.000

WIND RIVER STATISTICAL CPUE DATA SUMMARY

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
WRDNB	18	3.181	1.920	2.828	3.470	0.818
WRDNA	44	5.210	4.600	5.050	3.594	0.542
WRUPB	5	2.392	2.110	2.392	1.180	0.528
WRUPA	25	5.085	4.210	4.816	4.053	0.811
ALL	92	4.626	3.905	4.352	3.695	0.385

	MIN	MAX	Q1	Q3
WRDNB	0.000	12.000	0.510	5.705
WRDNA	0.000	14.290	2.130	7.155
WRUPB	0.850	4.000	1.425	3.500
WRUPA	0.000	16.360	1.980	7.095
ALL	0.000	16.360	1.945	6.113

REPORT F

Investigation of Northern Squawfish Concentrations in Tributaries to the Mainstem Columbia, Snake and Clearwater Rivers

Prepared by

Becky Ashe
Columbia River Inter-Tribal Fish Commission
509 Thain Rd., Lewiston, Idaho 83501

Roy E. Beaty
Columbia River Inter-Tribal Fish Commission
729 N.E. Oregon, Suite 200, Portland, Oregon 97232

Manuel P. Villalobos
Nez Perce Tribal Fisheries Department
P.O. Box, Lapwai, Idaho

1993 Annual Report

CONTENTS

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the following individuals for their assistance with data collection: Bob Samuels, Jennifer Oatman, and Bruce Williams (NPT Fisheries Department); Brian Zimmerman, Jed Volkman, Dave McKay and Brent Spencer (CTUIR Fisheries Department); Vem Spencer, Louis Case, Larry Cowapoo and Brian Conner (CTUIR Threemile Dam trap and haul crew) and Bill Duke (ODFW). Thanks also go to Dr. Dave Bennett and Tom Dresser (University of Idaho) for their assistance in electrofishing the Palouse River.

Special thanks go to Joe Oatman, Aaron Penney, Keith Kipp, Mike Tuell and Jack Yearout (Nez Perce Tribe college intern volunteers); Ryan Oatman, Tanya Taylor, Ezra Whitman, Janelle Whitman, Joe McKay, Abe Yearout, Cherylita Pierre, and Doug Holt (Lapwai High School/Nez Perce Tribe Summer Youth Program volunteers) and Bruce Lawrence (NPT Summer Youth Program Coordinator) for the many hours they spent assisting with field data collection and laboratory analysis of gut samples.

Laboratory analysis of stomach samples was accomplished primarily by Jack McCormack, Jennifer Oatman and Bob Samuels with assistance from Charlie Taylor and Bruce Williams. Ralph Roseburg (USFWS, Dworkshak NFH) was extremely helpful in providing CWT and PIT tag detectors.

Si Whitman (NPT Fisheries Manager) and Gary James (CTUIR Fisheries Manager) provided logistical support. We appreciate technical advice and information provided by Mark Shuck (WDW) and Glen Mendel (WDF), and the cooperation and interest of landowners adjacent to the Tucannon River.

Ken Collis, Blaine Parker and Kathy McRae (CRITFC predation project staff) provided invaluable logistical and technical support and valuable comments on this manuscript. We also thank Dale McCullough and Dave Peterson for their review and comments.

ABSTRACT

We investigated five tributaries to the mainstem Columbia, Snake and Clearwater rivers for northern squawfish spawning concentrations previously reported by biologists and local anglers. A total of 1,541 northern squawfish were captured from May 11 to July 25 in the upstream migration trap at Threemile Dam on the Umatilla River. The most likely explanation for the large concentration is that these fish are part of a spawning migration, composed either of adfluvial and/or resident fish or part of a random spawning distribution of mainstem fish. Alternative explanations for the large migration include: (1) reascension of

resident fish washed downstream by high spring flows; (2) predatory response to increased prey abundance (smolt outmigration); or *(3)* escape from unsuitable mainstem conditions (i.e., increased saturated gas concentrations).

Sampling efforts in the Palouse, Tucannon and Potlatch rivers, and Lapwai Creek were less successful at locating northern squawfish concentrations. Explanations include: (1) high spring flows may have limited our ability to capture migrating fish, (2) previously reported concentrations may not occur annually, or *(3)* previous removals may have reduced the number of northern squawfish available to migrate into tributaries.

INTRODUCTION

Large concentrations of northern squawfish (*Ptychocheilus oregonensis*) observed by both anglers and biologists at the mouths and in the lower reaches of tributaries to the Columbia, Snake and Clearwater rivers in spring months are probably spawning adults that have migrated upstream from the mainstem river. If fish concentrating in tributaries during certain times of the year can be confirmed as originating from the mainstem, then control efforts targeted on those concentrations may be an effective and efficient way to reduce mainstem predation by northern squawfish.

Life history information available from other water bodies, similar to Snake and Columbia river reservoirs, indicates that northern squawfish commonly migrate from lakes and reservoirs into free-flowing tributaries to spawn. Such migrations have been documented from Sixteenmile Lake, B.C. (Teraguchi 1962), and from Lake Coeur d'Alene, Idaho, (Reid 1971; Beamesderfer 1992; N. Homer, IDFG, pers. comm.). The construction of Post Falls Dam at the outlet of Lake Coeur d'Alene stabilized water levels in the lake and improved habitat for northern squawfish, which migrate up the St. Joe River and St. Maries River in April to spawn in June and July. The concentrations of northern squawfish in these two rivers are massive enough to cause considerable public dissatisfaction; control efforts by IDFG have focused on these spawning concentrations (N. Homer, IDFG, pers. comm.).

Elsewhere, northern squawfish from Cascade Reservoir (Payette River, tributary to Snake River), migrate up the North Fork Payette River and Gold Fork and Lake Fork creeks in May, where control efforts are targeted on these concentrations (Casey 1962; D. Anderson, IDFG, pers. comm.). In the Colorado River, Colorado squawfish (*Ptychocheilus lucius*), a closely related species to northern squawfish, migrate upstream to spawn (Tyus 1986; McAda and Kaeding 1991).

There is a great deal of anecdotal information available regarding concentrations of northern squawfish in tributaries to the Snake and Columbia rivers, although the purpose for these concentrations has never been documented. It is likely that the fish observed in these concentrations are manifesting a general life history pattern of migrating from reservoirs into free-flowing tributaries for spawning. Tributaries in which northern squawfish concentrations have been observed include the Umatilla River (a Columbia River tributary), the Palouse and Tucannon rivers (Snake River tributaries), and Potlatch River and Lapwai Creek (Clearwater River tributaries).

In the Umatilla River, hundreds of squawfish are incidentally captured from late April to mid-July every year in an upstream migration trap operated by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the Oregon Department of Fish and Wildlife (ODFW) at Threemile Dam on the Umatilla River (B. Zimmerman, CTUIR, unpublished data).

In the Palouse River, two anglers fishing at the outlet of the pool below Palouse Falls in late May/early June 1988, caught northern squawfish on virtually every cast from a concentration where the fish could be seen rolling and jumping (P. Bentley, NMFS, pers. comm.; J. Dedloff, WDF, pers. comm.). In addition, Merwin traps fished in the Palouse Arm captured a total of 34,607 northern squawfish in four years (Bentley et al. 1976).

In the lower Tucannon River, massive seasonal concentrations of northern squawfish have occurred just below an irrigation diversion dam (known as Fletcher's Dam) approximately two to three miles upstream of Star-buck, Washington (M. Schuck and S. Martin, WDW, pers. comm.; G. Mendel, WDF, pers. comm.). Northern squawfish, probably in the thousands, formed a dense mass across the entire river (60 feet wide) along a 100-foot section during April and May (M. Schuck, WDW, pers. comm.).

In June 1991, two anglers fishing in a short section of the lower mile of Potlatch River caught approximately 200 northern squawfish in a total of about seven hours from a concentration that was estimated to number in the thousands (local resident, pers. comm.).

At the mouth of Lapwai Creek, large northern squawfish can be caught each year as they enter the creek and migrate upstream, particularly in years with good spring flows (local resident, pers. comm.). Northern squawfish in spawning coloration were observed moving up the creek as early as March in 1992, a year with low spring flow (R. Beaty, CRITFC, pers. comm.).

The objectives of this study were to:

1) Investigate and document the presence of northern squawfish concentrations at the mouths, or in the lower reaches, of tributaries to the mainstem Columbia, Snake and Clearwater rivers, specifically the Umatilla, Palouse, Tucannon and Potlatch rivers, and Lapwai Creek.

2) Collect information that might help determine the purpose for northern squawfish concentrations in the tributaries, (e.g., sex, sexual maturity, and diet).

3) Compile anecdotal information about northern squawfish concentrations in other tributaries to the Snake and Columbia rivers.

METHODS AND MATERIALS

Study Areas and Sampling Methods

The Umatilla River (Columbia River tributary), the Palouse and Tucannon rivers (Snake River tributaries), and Potlatch River and Lapwai Creek (Clearwater River tributaries) were sampled for northern squawfish concentrations in 1993.

The Umatilla River empties into the Columbia River at Umatilla, Oregon, approximately 4.5 km downstream from McNary Dam (Figure F-l). The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and Oregon Department of Fish and Wildlife (ODFW) collected northern squawfish from May through July from an upstream migration trap located at Threemile Dam (approximately 4.5 km upstream from the mouth) on the Umatilla River operated to capture adult salmon and steelhead. The trap, a holding tank at the upstream end of the dam's fish ladder, was open 24 hours per day and was emptied each morning by CTUIR and ODFW employees. Incidentally caught northern squawfish were removed, enumerated, examined for tags or marks, and biological data was **collected (see Data Collection and Summary).**

The Palouse, Tucannon, and Potlatch rivers and Lapwai Creek were sampled biweekly. Although sampling was originally scheduled to begin in April, high spring run-off and excessive turbidity in all of the tributaries limited access and delayed sampling until late May. However, water temperature was measured periodically in each of the tributaries during April and May.

The Palouse River enters Lower Monumental Pool from the north at Lyons Ferry, Washington (Figure F-2). We intended to use backpack electrofishers to sample the 1 l-km reach between the mouth of the Palouse River and Palouse Falls, an impassable barrier to upstream-migrating fish. However, extremely high spring flows dictated that we use a boat electrofisher and restricted our sampling to June.

The Tucannon River enters Lower Monumental Pool from the south at Lyons Ferry, Washington (Figure F-2). From late May through July, we sampled from the mouth of the Tucannon River to Fletcher's Dam, an irrigation diversion dam approximately 8 km up the river, which is believed to be a migration barrier to northern squawfish (M. Schuck, WDW, pers. comm.). A backpack electrofisher was primarily used to collect northern squawfish, although hook-and-line was used where shocking was difficult or ineffective. Due to the potential impacts on chinook salmon listed under the Endangered Species Act (ESA) in the Tucannon River, extreme caution was used during sampling so as not to incidentally capture any salmonids. We used inwater observations and strict criteria to determine how to sample a site each sampling day:

1. Adult salmonid(s) present: no sampling.

2. Adult salmonids absent, juvenile salmonid(s) present: sample northern squawfish with hook-and-line.

3. Adult salmonids absent, juvenile salmonids absent: sample northern squawfish with backpack electrofisher and seines, if possible.

Potlatch River, the largest tributary of the lower Clearwater River system, enters the Clearwater River approximately 19 km upstream from its confluence with the Snake River at Lewiston, Idaho (Figure F-3). During field surveys, we determined that there were no migration barriers to northern squawfish in the lower 16 km of Potlatch River, however, due to time constraints and angler reports of northern squawfish concentration locations, we focused all sampling efforts in the lower 1.5 km of the river. Hook-and-line angling was used exclusively for sampling from May through mid-June. From mid-June through July, when flows subsided, backpack electrofishing was used.

Lapwai Creek joins the Clear-water River approximately 16 km upstream from its confluence with the Snake River (Figure F-3). We were unable to rind any obvious migration barriers to northern squawfish in the lower 16 km of Lapwai Creek, and based on angler reports, sampled only the lower 8 km of the creek. Primary method of capture was a backpack electrofisher; hook-and-line was used in areas where electrofishing was difficult or impossible. Sampling was conducted from late May through July.

In addition to the above mentioned sampling locations, other sites were investigated by interviewing biologists and anglers to gather anecdotal information about other major tributaries to the Columbia and Snake rivers in which northern squawfish may concentrate. Tributaries investigated included Hood River, Deschutes River, John Day River, Willow Creek Arm, Klickitat River, Grande Ronde River and Imnaha River. Information provided during the interviews is summarized in this report.

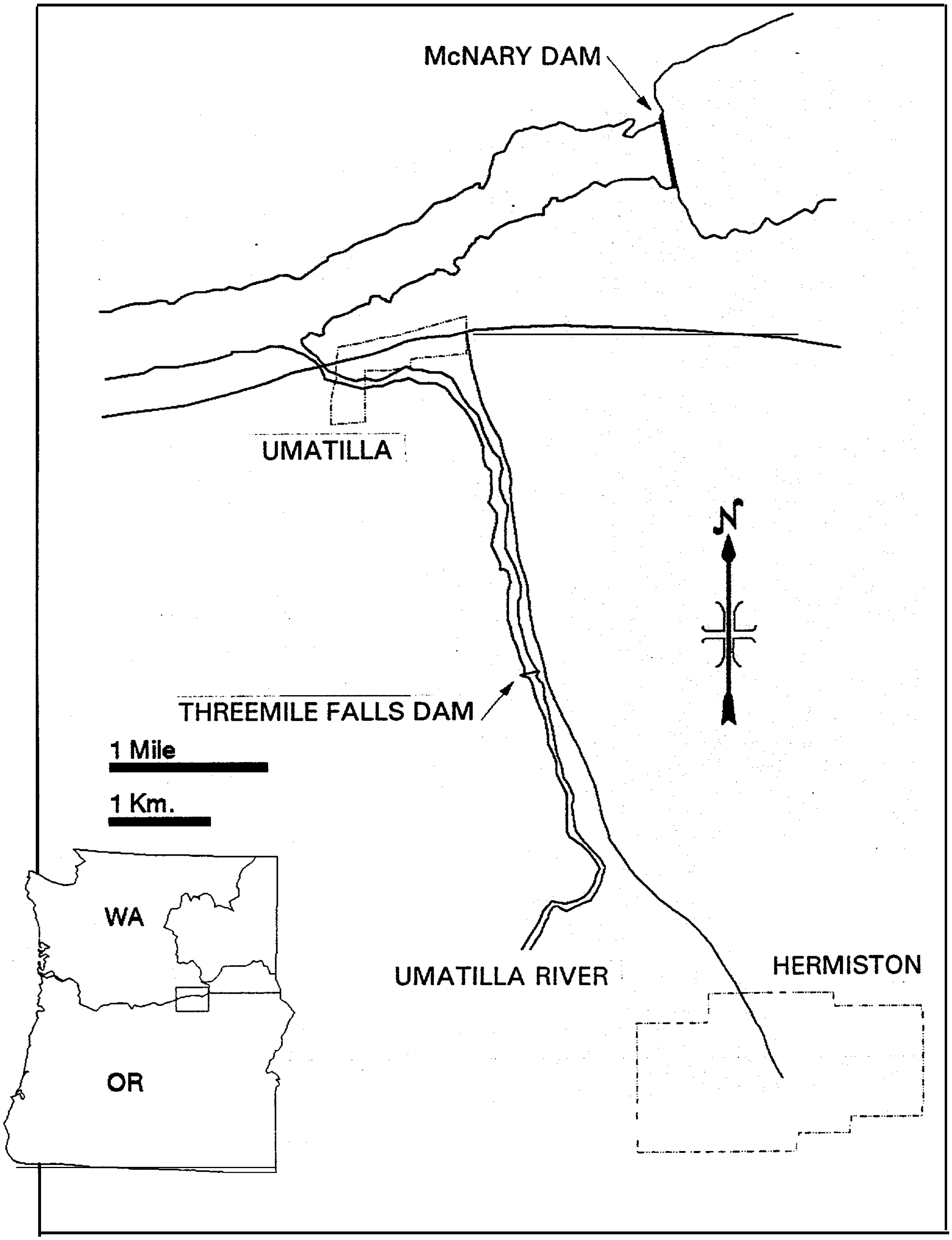


Figure F-l. Sampling area located at Threemile Falls Dam on the Umatilla **River.**

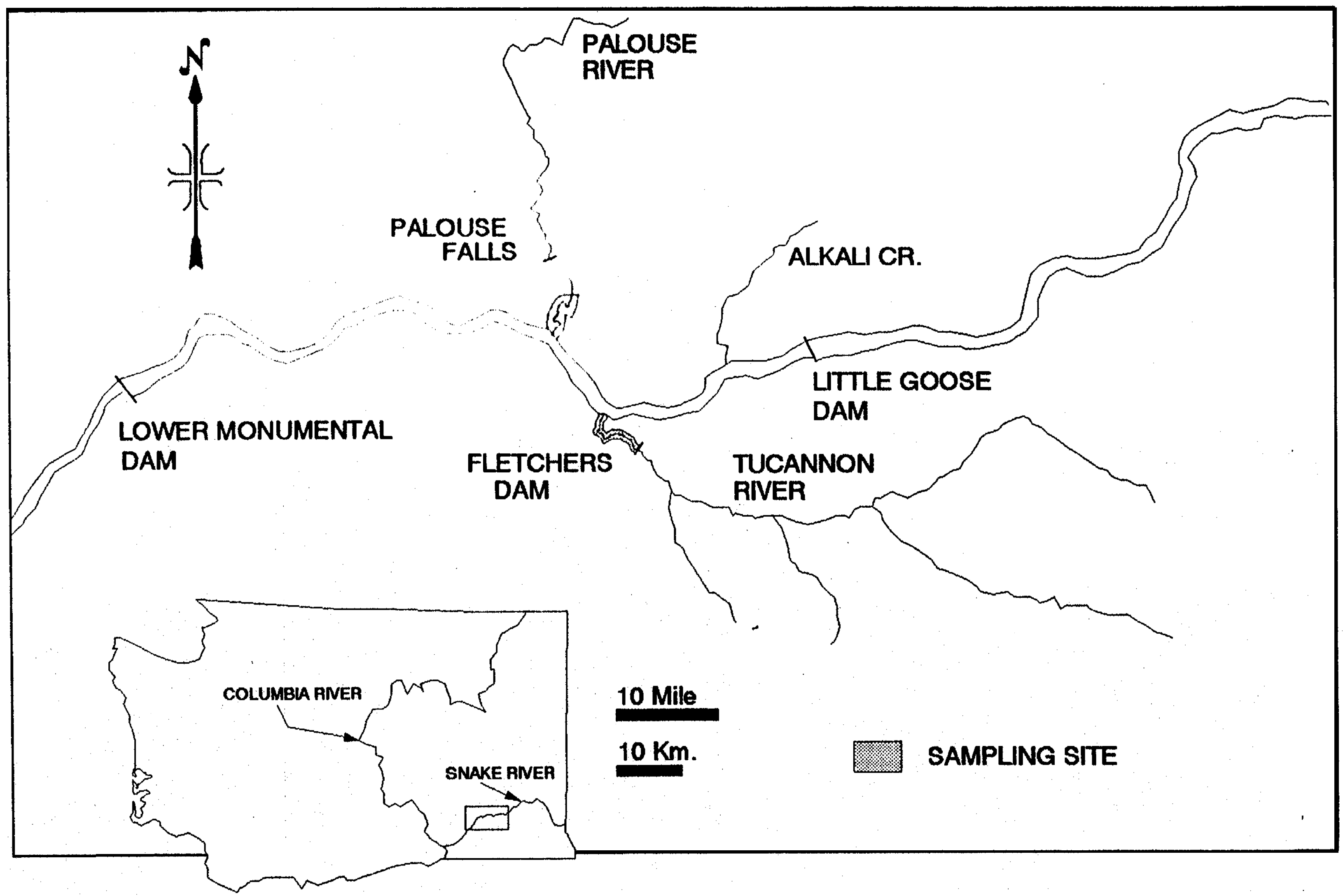


Figure F-2. Sampling locations in the Palouse River and the Tucannon River.

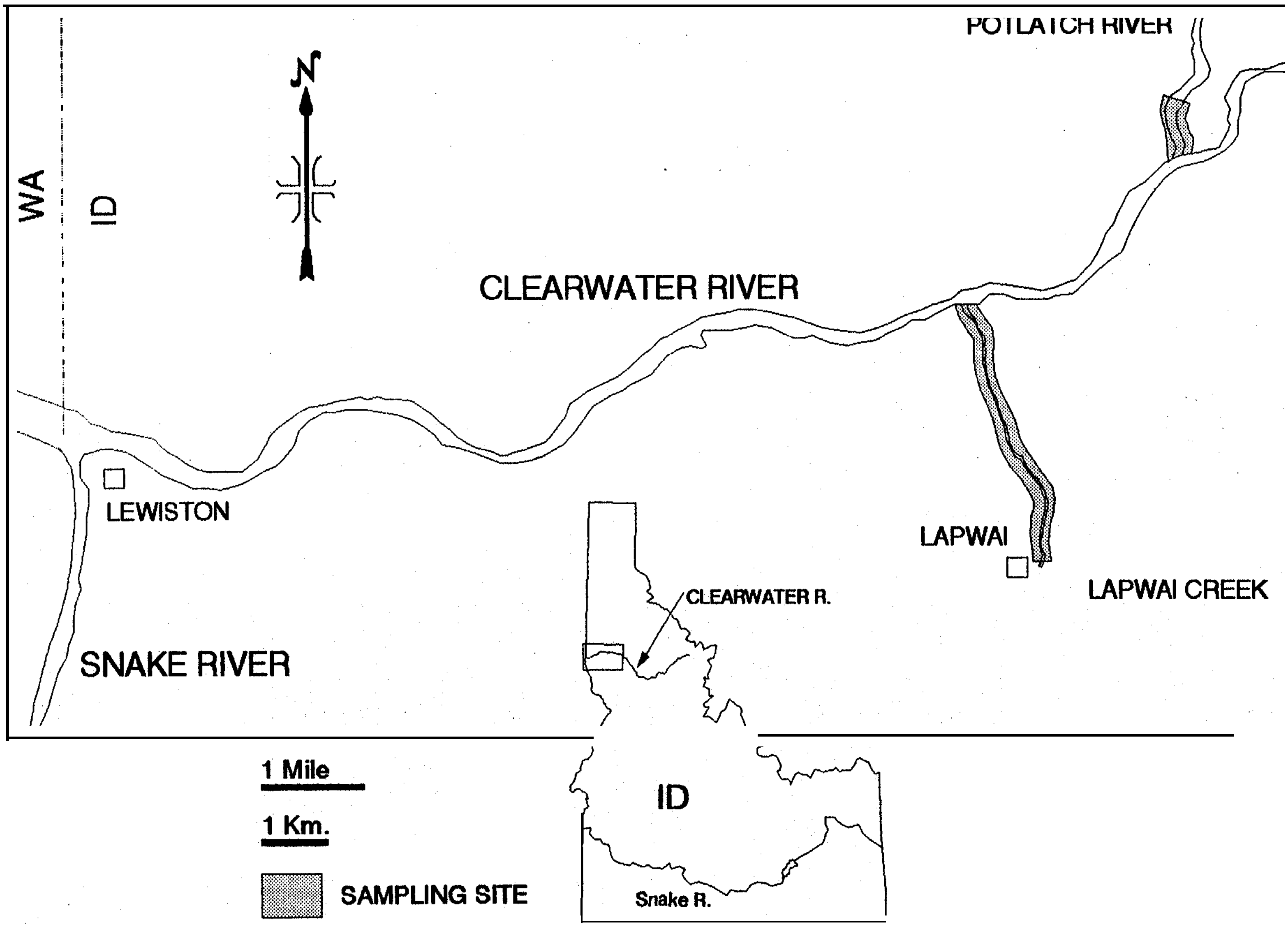


Figure F-3. Sampling locations on the Potlatch River and Lapwai Creek.

Data Collection and Summary

Northern squawfish captured and removed from the Threemile Dam migration trap were enumerated and checked for tags or marks daily by CTUIR and ODFW technicians. In 1993, carcasses were delivered to Washington Department of Wildlife (WDW) personnel at the check station in Umatilla. In previous years, northern squawfish caught in the trap were sacrificed and returned to the river. Arrival of northern squawfish at the Threemile Dam trap was compared to daily water temperature ("Celsius) readings in the Umatilla River at Threemile Dam; Umatilla River discharge (cfs) at Umatilla, Oregon; mainstem (Columbia River) water temperature (°C) at McNary Dam; and dissolved gas concentrations (percent saturation) below McNary Dam (B. Zimmerman, CTUIR, unpublished data; U.S. Army Corps of Engineers, unpublished data).

Northern squawfish captured in the Palouse, Tucannon and Potlatch rivers and Lapwai Creek were enumerated and examined for tags and fin clips. Total numbers of northern squawfish captured were reported (regardless of size), as was the number of predator- sized fish (≥275 mm). Incidentally caught species were also enumerated and then released unharmed. Northern squawfish not sacrificed for biological samples were measured, weighed, and marked with site-specific fin punches (fins were not excised), so that we could later identify recaptured individuals. Total northern squawfish catch reported here does not include recaptured individuals.

Biological information was collected weekly from 20 randomly selected northern squawfish captured in the Umatilla River and from all northern squawfish (up to a maximum of 10 per week) in the other four tributaries (Palouse, Tucannon, Potlatch and Lapwai). We recorded fork length (nearest mm), weight (nearest 10 g), and presence of external spawning characteristics (e.g., dark lateral bands and head tubercles). Gonads were examined to determine sex, and stage of maturity (undeveloped, developed, ripe or spent). Information collected on length, weight, sex and stage of maturity was summarized weekly and monthly for the Umatilla River. Due to small sample sizes, this information was summarized monthly for all other tributaries.

Gut samples were collected following the methods of Petersen et al. (1990), placed in plastic Whirlpak™ bags and preserved by freezing. Methods for analysis of gut contents were slightly modified from Petersen et al. (1990) and are detailed in Report E (Collis et al. 1995). Fish found in northern squawfish gut samples were identified to family. Percent composition (by weight) of prey items found in the gut were summarized by month for each tributary.

RESULTS AND DISCUSSION

A total of 1,686 northern squawfish were captured during our tributary sampling, most (91%) of which were from the Umatilla River (Table F-l). We observed and captured very few fish in the Palouse, Tucannon and Potlatch rivers, and Lapwai Creek.

Umatilla River

A total of 1,541 northern squawfish were captured in the migration trap at Threemile Dam during 63 days of trap operation (Table F-l). Reportedly, none of the fish captured in the trap during this study bore tags or marks. The first northern squawfish arrived at the trap May 11, and the last fish was captured July 25. The majority (58%) were caught during a one-week period, following an increase in the average weekly water temperature from 15°C to 18°C (Figure F-4) and a decrease in the average weekly flow from 1,705 cfs to 419 cfs (Figure F-5). See Appendix Table F-l. 1 for a weekly catch summary.

We collected biological information and samples from 118 (8 % of the total catch) northern squawfish. Our sample was composed of 41% females and 59% males (Table F-2). Of the fish we sampled, 89% were predator size ($\geq$275 mm). See Appendix Table F-l.2 for a weekly summary of biological data.

The sizable migration of northern squawfish up the Umatilla River appears to be the first documented in a tributary to the Columbia River. Although large numbers of northern squawfish have been captured in the Threemile Dam trap for at least the past three years (B. Zimmerman, CTUIR, unpublished data), there is no conclusive evidence as to the cause(s) for these migrations. Determining the origin and cues responsible for the large migrations of northern squawfish in the Umatilla River could play a significant role in describing life history patterns of northern squawfish in the Columbia River system, and therefore be important in developing management activities aimed at reducing predation by northern squawfish on juvenile salmonids.

Table F-1. Sampling effort and catch by tributary.

Location	Gear type	Effort	Northern Squawfish[1]	Salmonids Adult	Salmonids Juvenile	Game Fish[2]	Other
Umatilla River	UT	63.0	1541	n/a[3]	n/a[3]	n/a[3]	n/a[3]
Palouse River	HL	0.0	0	0	0	0	0
	EF	4.3	1	0	0	270	260
Tucannon River	HL	2.6	4	0	0	0	64
	EF	1.3	64	0	1	15	466
Potlatch River	HL	15.2	7	0	0	11	2
	EF	0.9	1	0	0	13	50
Lapwai Creek	HL	8.8	1	0	0	2	1
	EF	1.5	67	0	0	12	136
TOTALS		n/a	**1686**	**0**	**1**	**323**	**979**
FISH CONDITION							
Good				0	1	323	979
Fair				0	0	0	0
Dead				0	0	0	0

GEAR TYPE - DEFINITION OF EFFORT

UT - Upstream migration trap - Days (trap operated approximately 24 $hr \cdot d^{-1}$)

HL - Hook and line - Angler h

EF - Electrofishing - Shocking time (h)

[1] Numbers reported are not all predator size (≥275 mm) northern squawfish. See detailed size composition data in Appendix Tables F-1.3 through F-1.5.
[2] See Table F-4 for game fish composition by species.
[3] Northern squawfish were captured incidentally in the trap designed to capture adult salmonids, therefore reporting incidental catch of other species is not applicable.

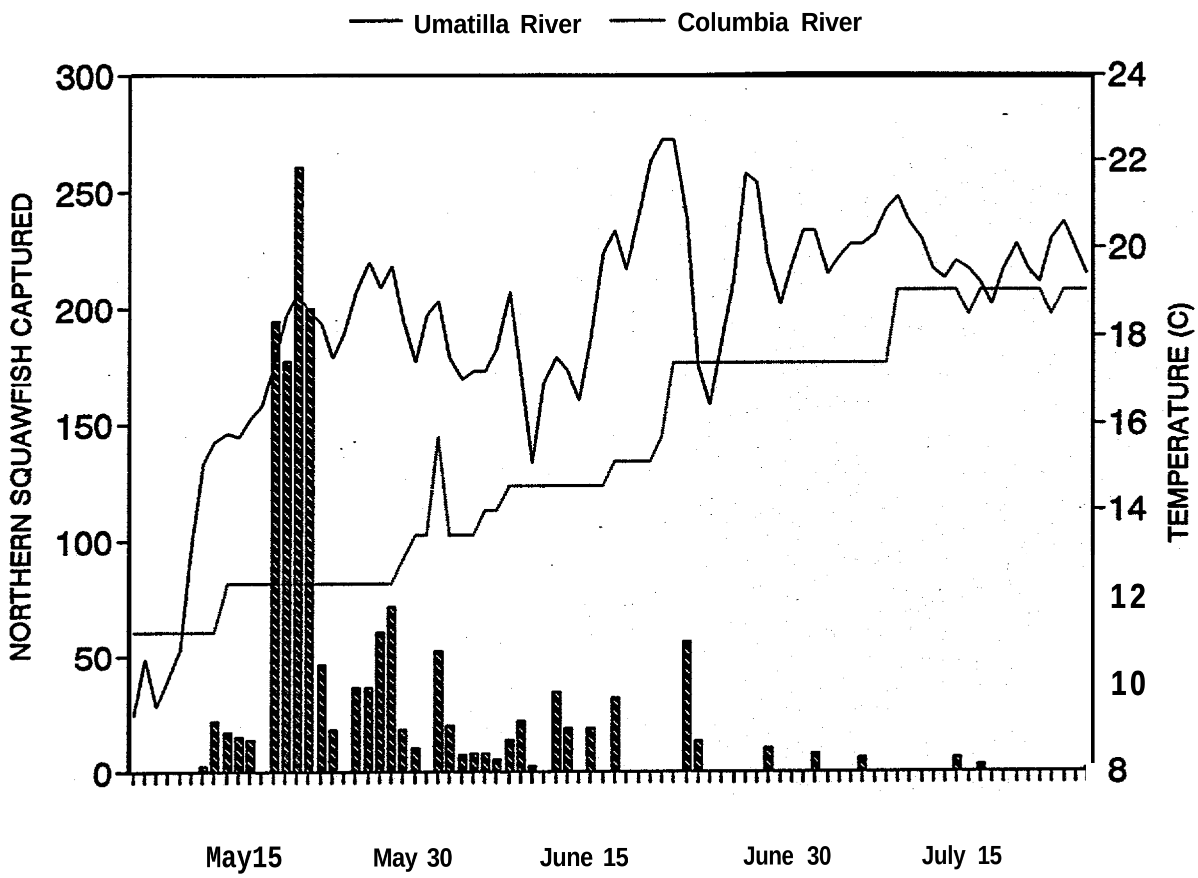


Figure F-4. Daily counts of northern squawfish captured in the Umatilla River and water temperatures (°C) in the Umatilla River at Threemile Dam (B. Zimmerman, CTUIR, unpublished data) and Columbia River below McNary Dam (USACE, unpublished data).

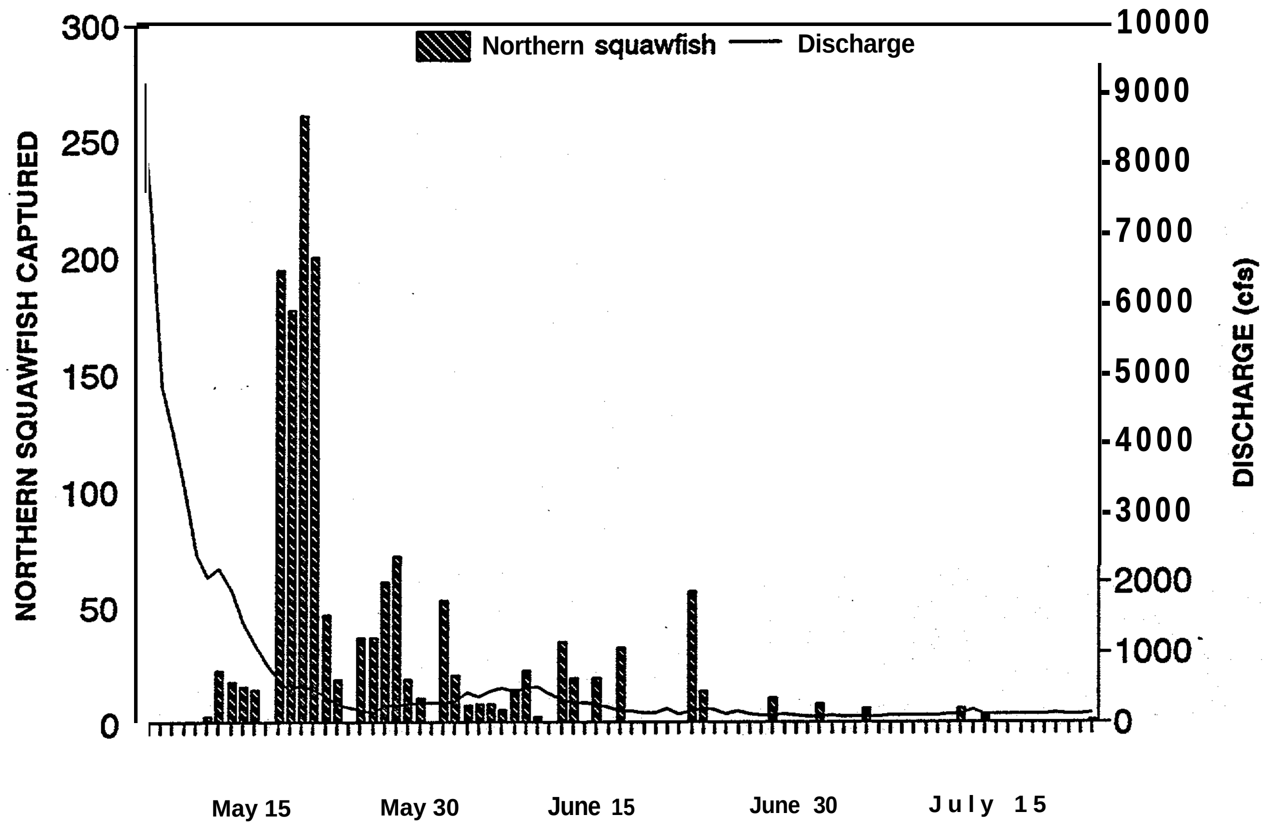


Figure F-5. Daily counts of northern squawfish captured in the Umatilla River and Umatilla River discharge (cfs) at Umatilla, Oregon (B. Zimmerman, CTUIR, unpublished data).

Table F-2. Length, weight and sexual maturity data from northern squawfish captured in the **Umatilla River.**

	May		June	
	Females	Males	Females	Males
Sample size	27	33	21	37
Length: Mean	361	310	330	300
Range	3 14-400	240-394	227-477	238-390
Weight: Mean	553	349	501	354
Range	370-750	190-500	150-760	150-640
Stage of maturity (%)				
Undeveloped			29	14
Developing	100	100	48	57
Ripe			24	24
Spent				5

We believe there are several alternative explanations for the large numbers of northern squawfish in the Umatilla River migration trap: (1) reascension of resident fish washed downstream by high spring flows; (2) predatory response to increased prey abundance (outmigrating smolts); (3) escape from unsuitable mainstem conditions, (i.e., increased saturated gas concentrations); or (4) spawning concentrations, either of resident and/or adfluvial populations, or part of a random spawning distribution of mainstem fish.

Adult northern squawfish may be washed out of the Umatilla River by high spring flows and then attempt to reascend over Threemile Dam as flows decrease. This alternative is supported by the flow-arrival timing relationship (Figure F-5) and the reported absence of tags and marks, which suggests these fish did not spend much time, if any, in the mainstem. We are skeptical, however, that this scenario would provide the magnitude of run witnessed in 1993, and it does not explain the movement of fish witnessed in 1992 during an extremely low flow year.

Although the timing is similar, results of gut content analysis imply that northern squawfish movement into the Umatilla River is not to feed on outmigrating smolts. Smolt migration in the Umatilla River is directly related to flow (G. Rowan, CTUIR, pers. comm.). During high flow years like 1993, salmonid smolts typically outmigrate from late April through early June, with a peak in early May (G. Rowan, CTUIR, pers. comm.) All of the 118 gut samples we collected were empty, with the exception of one that contained diagnostic bones only of one juvenile salmonid (Table F-3).

Another alternative is that northern squawfish captured in the Umatilla River trap may simply be seeking refuge from less favorable environmental conditions in the mainstem. Due to the proximity of McNary Dam, northern squawfish in the mainstem adjacent to the mouth of the Umatilla River are subjected to alterations in the environment caused by dam operation. Appearance of northern squawfish in the Umatilla River appears to be related to dissolved gas concentrations below McNary Dam (Figure F-6). Bentley et al. (1976) and Sims et al. (1976) suggested that large numbers of northern squawfish concentrated in the Palouse Arm (a tributary several miles downstream from Little Goose Dam) to escape the high levels of dissolved gasses in the Snake River. Movement may also be related to selectivity of water temperature. Temperatures in the Umatilla River were warmer earlier than those in the mainstem in 1993 (Figure F-4).

Despite the apparent relationship between northern squawfish movement up the Umatilla River and unfavorable mainstem conditions, this alternative is questionable because we would not expect fish seeking refuge from mainstem conditions to expend the energy to migrate three miles up the Umatilla River. In addition, proving a cause and effect relationship in this situation would be difficult due to the many environmental variables affecting fish behavior and movement.

Table F-3. Gut content analysis of northern squawfish captured in **the Umatilla River.**

	May	June
Sample size	60	58
Guts containing prey items	0[1]	0
Weight composition (%)		
Fish	0	0
Crustacea	0	0
Mollusca	0	0
Insecta	0	0
Plants	0	0
Other	0	0
Salmonids	1[1]	0
Cyprinids	0	0

[1] Diagnostic bones of one juvenile salmonid were found, although no prey had been noted when gut contents were originally examined.

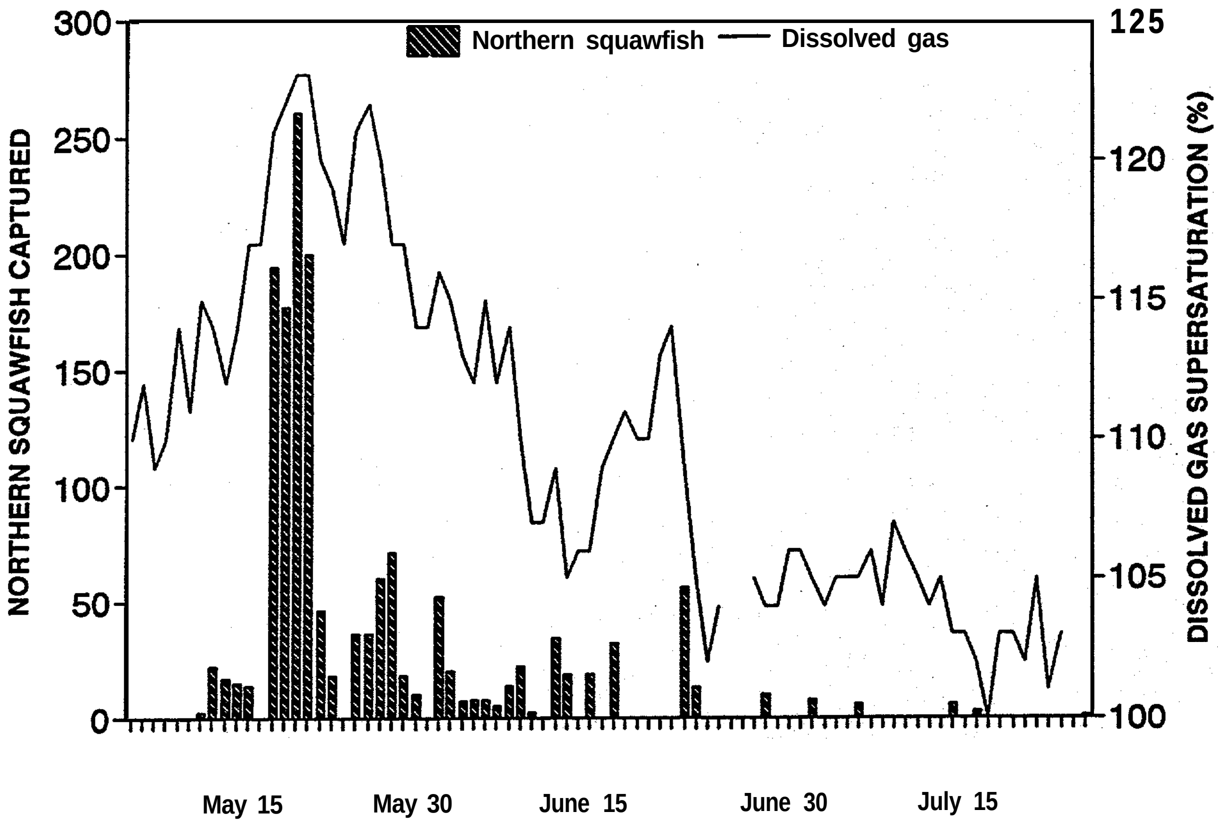


Figure F-6. Daily counts of northern squawfish captured in the Umatilla River and dissolved gas supersaturation (%) recorded below McNary Dam (USACE, unpublished data).

The most likely explanation, based on our data and other evidence,. is that these fish are part of a spawning migration. Arrival of northern squawfish in the Umatilla River trap followed a rapid increase in water temperature (Figure F-4) and decrease in flow (Figure F-5), which have been identified as important factors regulating the seasonal timing of spawning by northern squawfish in other tributaries (Keating 1958, Hill 1962, Reid 1971, Beamesderfer 1992). According to Jeppson and Platts (1959), northern squawfish congregate on the spawning ground when the water temperature nears 60" Fahrenheit (15°C). The first day northern squawfish were captured in the Umatilla River trap followed an increase in water temperature from 13°C on May 10 to 15°C on May 11. Similar activity was noted by trap personnel in 1992, when the first day large numbers were captured followed an increase in water temperature to 59°F (15°C; B. Zimmerman, CTUIR, unpublished data).

To determine if the northern squawfish captured in the Umatilla River were in spawning condition, we examined gonad maturity weekly. None of the fish (either sex) we examined in May were ripe. However, in June 24% of both males and females were ripe and 5 % of the males were already spent (Table F-2). These results are very similar to data collected from northern squawfish captured at McNary Dam in 1991 (a similar water year to 1993), which indicated that spawning occurred in June and July (Ward et al. 1991). The arrival of still-developing fish at the Umatilla River trap in May is similar to behavior displayed by northern squawfish in the St. Joe and St. Maries rivers, Idaho, where concentrations of fish arrive and stage on the spawning grounds several weeks before actual spawning begins (N. Homer, IDFG, pers. comm.).

Despite the strong similarities of northern squawfish migrations in the Umatilla River to movement of known spawning migrations in other river systems, we were unable to prove that the Umatilla River migration was for spawning. Because all northern squawfish were removed from the system at Threemile Dam, we were unable to observe spawning activity in the tributary.

If spawning is the driving force behind the northern squawfish migrations in the Umatilla River, the origin of these fish becomes an important question. There appears to be two major alternatives to their origin, both with significant implications to the effectiveness of the predator control program.

The northern squawfish we captured may be offspring of resident populations upstream of the migration trap. As juveniles, these fish may have been flushed, or migrated of their own volition, to the mainstem Columbia during high spring flows. The major implication of this scenario is that tributary populations of northern squawfish, either resident or adfluvial, may be a major source of mainstem predators. If tributary spawning accounts for a substantial portion of mainstem predators, then removal of adults entering tributaries could be an effective control measure for mainstem predation. In the Umatilla River, however, this alternative is not supported by the continuous high catches of northern squawfish at Threemile Dam. We would expect the magnitude of catches to decline after several years of 100% removal, because the repeat spawners would be eliminated from the population.

The second alternative is that the trapped northern squawfish originated from mainstem populations and that the large movement up the Umatilla River is a result of random spawning distribution. The lack of tagged or marked fish suggests the fish captured in the Umatilla River trap have not spent a great deal of time in the mainstem, however, we are not confident that each fish was examined carefully. Sexual maturity data collected at McNary Dam (Ward et al. 1991) supports this alternative, as it indicates that mainstem northern squawfish are in spawning condition at the same time migrations are occurring up the Umatilla River. Implications of this scenario are: (1) tributaries may be a major source of mainstem predators and therefore removal at the mouth of Umatilla River, and possibly any other tributary, is equivalent to the removal from the mainstem; and (2) northern squawfish populations in the Columbia River system would not be discrete, therefore making extirpation unlikely.

Despite the enormous research efforts being devoted to northern squawfish in the Columbia River Basin, very little is known about spawning habits or the complete life history of mainstem populations. Radio telemetry studies have yet to document "spawning grounds" or localized concentrations of northern squawfish during spawning season (Rip Shively, USFWS, pers. comm.). However, the results of radio telemetry studies to date may be limited by sample size and/or an insufficient number of tagged males. Female northern squawfish are probably chosen for radio tag implantation more frequently than males due to their larger size. Male northern squawfish arrive at the spawning area early and remain for some time, while the ripe females are on the site only when they spawn (Wydoski and Whitney 1979). This coincides with observations by Jeppson and Platts (1959) in Merwin Reservoir and Beamesderfer (1992) in the St. Joe River, where males outnumbered females on the spawning ground by 50-200: 1. Based on this information, radio tracking males may be a more effective method to locate spawning areas.

Conclusions as to origin of northern squawfish trapped in the Umatilla River and purpose for their migration can not be made based on the limited amount of data we collected. We recommend continued monitoring of fish captured in the migration trap at Threemile Dam for the presence of tags or marks, sex and stage of maturity data and that surveys be conducted below Threemile Dam to search for evidence of spawning concentrations. We also recommend collecting information on movement and behavior of fish migrating in the Umatilla River by radio telemetry. Northern squawfish should be captured and tagged at the mouth of the Umatilla River to determine what cues might effect upstream migration. Fish captured in the Threemile Dam trap should also be tagged and released above the dam to determine movement and behavior.

Snake and Clearwater River Tributaries

We captured a total of 145 northern squawfish from the Palouse, Tucannon and Potlatch rivers, and Lapwai Creek combined (Table F-l). Due to high spring runoff and turbidity, sampling in these four tributaries was often difficult, if not impossible. Backpack electrofishing was the most effective method of capture, accounting for 92% of our northern squawfish catch.

We captured one northern squawfish in the Palouse River during 4.3 h of boat electrofishing (Table F-l). Over 500 game and non-game fish were incidentally captured, composed primarily of black crappie, pumpkinseed and suckers (Table F-4).

In the Tucannon River we captured 68 northern squawfish (Table F-l). The majority of these were captured immediately downstream from Fletcher's Dam (Figure F-2). At this same location we also captured large numbers of chiselmouth and suckers (Table F-4) from what appeared to be spawning concentrations.

Sampling in Potlatch River yielded eight northern squawfish, of which seven were captured by hook-and-line at the mouth of the river (Table F-l). We captured 68 northern squawfish in Lapwai Creek (Table F-l), the majority of which found in deep pools within 1.5 km from the mouth of the creek.

We captured one salmonid during our sampling, a juvenile rainbow trout (or steelhead) with an adipose fin in the Tucannon River (Table F-4). It was released in good condition.

Gut content analysis indicated that the fish we sampled were not in the tributaries to feed on juvenile salmonids. Ninety-seven percent of the gut samples from the Tucannon River were empty (Table F-5). Northern squawfish in the Potlatch River were feeding mainly on insects and crayfish (Table F-6) and in Lapwai Creek were feeding almost exclusively on crayfish (Table F-7). Biological information collected on length, weight, and sexual maturity can be found in Appendix Tables F-1.6-8.

There are two hypotheses that may explain our unsuccessful efforts to document northern squawfish concentrations in the Palouse, Tucannon and Potlatch rivers, and Lapwai Creek: (1) concentrations were present in the tributaries, but we were not able to capture them; or (2) concentrations were not present in the tributaries in 1993.

Environmental conditions in the tributaries in 1993 were very different from 1991 and 1992. During spring runoff (late May-early June) it was difficult and sometimes impossible to access the tributaries. In addition, our sampling equipment was seriously limited in its effectiveness during the high flows. The majority (58%) of northern squawfish collected in the Umatilla River were captured in one week, during which time the average flow was 419 cfs. If this scenario was similar in the other four tributaries, concentrations may not have been intercepted due to the biweekly sampling schedule and the ineffectiveness of our sampling gear.

Table F-4. Species composition of game fish and non-game fish incidentally captured during tributary sampling. All fish were released unharmed and in good condition.

	Palouse River	Tucannon River	Potlatch River	Lapwai Creek	Total
Rainbow trout (steelhead) *Onchorynchus mykiss*	0	1	0	0	1
Smallmouth bass *Micropterus dolomieui*	49	14	24	14	101
Catfish *Ictaluris* spp.	16	1	0	0	17
Black crappie *Pomoxis nigromaculatus*	154	0	0	0	154
Pumpkinseed *Lepomis gibbosus*	150	0	0	0	150
Yellow perch *Perca flavescens*	51	0	0	0	51
Chiselmouth *Acrocheilus alutaceus*	0	366	23	99	488
Redside shiner *Richardsonius balteatus*	0	0	10	0	10
Peamouth *Mylocheilus caurinus*	1	0	0	0	1
Carp *Cyprinus carpio*	44	0	0	0	44
Suckers *Catostomus* spp.	65	164	19	38	286

Table F-5. Gut content analysis of northern squawfish captured in the **Tucannon River.**

	June	July
Sample size	28	3
Guts containing prey items	0	1
Weight composition. (%)		
Fish	0	0
crllstacea	0	0
Mollusca	0	0
Insecta	0	0
Plants	0	100
Other	0	0
Salmonids	0[1]	0
Cyprinids	0	0

[1] Remnants of salmonid scales were found in 3 gut samples--no diagnostic bones were evident.

Table F-6. Gut content analysis of northern squawfish captured in the Potlatch River.

	June	July
Sample size	4	4
Guts containing prey items	4	4
Weight composition (%)		
Fish	2.8	0
Crustacea	44.1	0
Mollusca	0	0
Insecta	23.4	100
Plants	29.7	0
Other	0	0
Salmonids	0	0
Cyprinids	1[1]	0

[1] Northern squawfish fry.

Table F-7. Gut content analysis of northern squawfish captured in **Lapwai Creek.**

	June	July
Sample size	10	25
Guts containing prey items	7	13
Weight composition (%)		
Fish	5.9	1.8
Crustacea	94.1	98.2
Mollusca	0	0
Insecta	0	0
Plants	0	0
Other	0	0
Salmonids	0	0
Cyprinids	1[1]	2[1]

[1] Northern squawfish fry.

It is also possible that northern squawfish were not present in the tributaries. Tributary concentrations witnessed by biologists and local residents in the past few years may not occur annually.

Another explanation is that the local concentrations of northern squawfish previously reported in the tributaries sampled have been heavily exploited by local anglers participating in the sport-reward program during the past three years. During our investigation, many of the locals we talked to were very knowledgeable about northern squawfish "hot spots" in the tributaries and which lures or baits were the most effective. Mainstem removals as a result of the sport-reward fishery and the dam-angling fishery may also be responsible for the few numbers of fish we encountered. Approximately 100,000 northern squawfish ($\geq$ 275 mm) reportedly have been removed from the Snake River reservoirs during the past three years, 80,032 by the sport-reward program (D. Klaybor, WDW, pers. comm.) and 19,968 by the dam-angling fishery (B. Parker, CRITIC, pers. comm.).

Although we were unable to document northern squawfish concentrations in the Palouse, Tucannon and Potlatch rivers, and Lapwai Creek this year, we do not believe efforts expended in this direction are futile. Until spawning '*grounds" and behavior are documented in the Columbia and Snake rivers, we believe monitoring mainstem tributaries for northern squawfish concentrations are worthwhile and may provide important information on the life history of northern squawfish allowing for more effective predator control efforts.

Information Survey

Our survey of local anglers and biologists indicated that similar migrations or concentrations may occur in other tributaries to the Columbia and Snake rivers. Large numbers of northern squawfish have been observed at, or near, the mouth of the Klickitat River, the Deschutes River, the John Day River and the Grande Ronde River (Table F-8).

Table F-8. Information survey summary of observations of northern squawfish concentrations in tributaries to the Columbia and Snake rivers. Northern squawfish is abbreviated NSF.

Location	Observation	Reference
	COLUMBIA RIVER	
Klickitat River	• Anglers report catching NSF from mouth up to Fisher Hill Bridge (approximately 3.2 km from mouth). • Tribal fisherman has caught numerous NSF below and in falls at Fisher Hill Bridge. • ODFW evaluation crew experienced an average gillnet catch of 46.5 NSF per net hour at the mouth in 1993.	John Weinhemer, WDW, pers. comm.; Roy Sampson, YIN, pers. comm.; ODFW, unpub. data
Hood River	No NSF concentrations have been documented in lower sections of river or at Powerdale Dam fish trap (approximately 8 km from mouth).	Jim Newton, ODFW, pers. comm.
Deschutes River	In 1992, anglers reported catching 50-60 NSF in a short period of time at the mouth.	Jim Newton, ODFW, pers. comm.
John Day River	• In 1956, the highest catch rate of NSF of 18 Columbia River tributaries sampled was at the confluence. • No recent reports of NSF concentrations, however, few investigations in the lower section of river.	USFWS, 1957; Jim Newton and Jim Phelps, ODFW, pers. comm.
Willow Creek Arm	No available information on non-game species.	John Germand, ODFW, pers. comm.
	SNAKE RIVER	
Grande Ronde River	• Large numbers of NSF captured at mouth during electrofishing surveys. • Local anglers have caught NSF at the mouth and as far upstream as Lookingglass Hatchery.	Tom Poe, USFWS, pers. comm.; local resident, pers. comm.
Imnaha River	NSF concentrations observed near mouth during late-spring and early-summer months.	Local resident, pers. comm.

RECOMMENDATIONS

1. Continue monitoring and sampling efforts at the Threemile Dam trap on the Umatilla River.

2. Survey the Umatilla River below the Threemile Dam trap looking for evidence of spawning concentrations.

3. Radio tag northern squawfish captured in Threemile Dam trap and release upstream to determine purpose for migration, and possibly origin.

4. Capture and tag northern squawfish at the mouth of the Umatilla River to evaluate migration up the Umatilla River.

5. Monitor tributaries and holes of known historical northern squawfish concentrations, (e.g. Fletcher's Dam on the Tucannon River) but do not take biological samples.

REFERENCES

Beamesderfer, R.C. 1992. Reproduction and early life history of northern squawfish, ***Ptychocheilus oregonensis,*** in Idaho's St. Joe River. Environmental Biology of Fishes 35:231-241.

Bentley, W.W., E.M. Dawley, and T.W. Newcomb. 1976. Some effects of excess dissolved gas on squawfish, ***Ptychocheilus oregonensis*** (Richardson). Pages 41-46 in D.H. Fickeisen and M.J. Scheider, editors. Gas bubble disease: proceedings of a workshop held at Richland, Washington, Oct. 8-9, 1974. Energy Res. Div. Admin. Office of Public Affairs, Tech. Inf. Center, Oak Ridge, TN.

Bentley, W.W., and E.M. Dawley. 1981. Effects of supersaturated dissolved atmospheric gases on northern squawfish, ***Ptychocheilus oregonensis.*** Northwest Science 55(1):50-61.

Casey, O.E. 1962. The life history of the northern squawfish in Cascade Reservoir. M.S. Thesis. University of Idaho, Moscow. 47 pp.

Collis, K., R. B. Beaty, B. Ashe, G. Lee, B. Parker, and K. McRae. 1995. Removal of predaceous northern squawfish found near hatchery release sites in Bonneville Pool: an analysis of changes in catch rates and diet associated with the release of hatchery-reared juvenile salmonids. Pages XX-XX in C.F. Willis and D.L. Ward, editors. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1993 Annual Report, Vol. 1. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

Faler, M.P., L.M. Miller, and K.I. Welke. 1988. Effects of variation in flow on distributions of northern squawfish in the Columbia River below McNary Dam. North American Journal of Fisheries Management 8:30-35.

Hill, C.W. Jr. 1962. Observations on the life histories of the peamouth (*Mylocheilus caurinus*) and the northern squawfish (*Ptychocheilus oregonensis)* in Montana. Proceedings of the Montana Academy of Sciences 22:27-44.

Jeppson, P.W. and W.S. Platts. 1959. Ecology and control of the Columbia squawfish in northern Idaho lakes. Transactions of the American Fisheries Society 88:197-202.

Keating, J.F. Jr. 1958. An investigation of the spawning habits and movements of non-game fish species, particularly squawfish, and evaluation of the findings regarding possible methods of control, Annual Report, Project F 22-R-4. Idaho Department of Fish and Game, Boise. 29 pp.

McAda, C.W., and L.R. Kaeding. 1991. Movements of adult Colorado squawfish during the spawning season in the Upper Colorado River. Transactions of the American Fisheries Society 120:339-345.

Petersen, J.H., D.B. Jepsen, R.D. Nelle, R.S. Shively, R.A. Tabor, and T.P. Poe. 1990. System-wide significance of predation on juvenile salmonids in Columbia and Snake River reservoirs. 1990 Annual Report. Contract DE-AI79-90BP07096, Bonneville Power Administration, Portland, Oregon. 53 pp.

Reid, G.E. 1971. Life history of the northern squawfish, *Ptychocheilus oregonensis* (Richardson), in the St. Joe River, Idaho. M.S. Thesis. University of Idaho, Moscow. 61 pp.

Sims, C.W., R.C. Johnson, and W.W. Bentley. 1976. Effects of power peaking operations on juvenile salmon and steelhead migrations, 1975. NOAA, NMFS, Northwest Fisheries Center, Seattle, Washington. Progress Report to U.S. Army Corps of Engineers.

Teraguchi, M. 1962. Migrations of northern squawfish, ***Ptychocheilus oregonense*** in streams tributary to Sixteenmile Lake, British Columbia. B.S. Thesis. University of British Columbia, Vancouver. 44 pp.

Tyus, H.M. 1986. Life strategies in the evolution of the Colorado squawfish (***Ptychocheilus lucius***). Great Basin Naturalist **46:656-661.**

USFWS (United States Fish and Wildlife Service). 1957. Squawfish predation study. 1957 Progress Report. U.S. Fish and Wildlife Service, Portland, Oregon.

Ward, D. L., M. P. Zimmerman, R. M. Parker, and S. S. Smith. 1991. Development of a system-wide predator control program: indexing, fisheries evaluation, and harvesting technology development. Pages 343432 ***in*** C.F. Willis and A. A. Nigro, editors. Development of a system-wide predator control program: **stepwise** implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1991 Annual Report. Contract **DE-BI70-90BP07084,** Bonneville Power Administration, Portland, Oregon.

Wydoski, R. S., and R. R. Whitney. 1979. Inland fishes of Washington. University of Washington Press, Seattle. 220 pp.

APPENDIX F-1

Tabular Data

Appendix Table F-1.1. Weekly summary of number of northern squawfish captured in migration trap at Threemile Dam (Umatilla River), temperature (°C) at Threemile Dam and flow (cfs) at Umatilla (B. Zimmerman, CTUIR, unpublished data).

Dates	Statistical Week	Squawfish captured	Mean temperature	Mean flow
5/3-5/9	19	0	9.9	5027
5/10-5/16	20	70	15.4	1705
5/17-5/23	21	895	18.2	419
5/24-5/30	22	231	18.8	229
5/31-6/6	23	114	17.8	385
6/7-6/13	24	93	16.9	357
6/14-6/20	25	32	21.1	162
6/21-6/27	26	69	19.2	145
6/28-7/4	27	18	19.7	88
7/5-7/11	28	6	20.5	84
7/12-7/18	29	9	19.3	117
7/19-7/25	30	1	19.9	118
Total		1541		

Appendix Table F-1.2. Length, weight and sexual maturity data from northern squawfish captured in the Umatilla River.

Statistical week	20	21	22	23	24	25	26
				Females			
Sample size	13	9	-	5	7	3	11
Mean length (mm)	373	351	-	346	340	356	317
Range (mm)	335-400	314-388	-	340-353	227-477	339-380	230-397
Mean weight (g)	560	549	-	544	529	600	457
Range (g)	400-750	370-740	-	490-620	310-750	560-670	150-760
Stage of maturity (%)							
Undeveloped					29	33	27
Developing	100	100		100	71	33	36
Ripe						33	36
Spent							
				Males			
Sample size	7	11	-	15	11	16	9
Mean length (mm)	339	295	-	307	305	298	301
Range (mm)	290-375	266-338	-	240-394	248-334	250-390	238-376
Mean weight (g)	426	296	-	351	385	338	342
Range (g)	300-500	200-500	-	190-440	180-550	210-520	120-640
Stage of maturity (%)							
Undeveloped					9	25	
Developing	100	100		100	36	75	56
Ripe					55		22
Spent							22

Appendix Table F-1.3. Results of sampling efforts in the Tucannon River, May-June 1993.

Date (Statistical week)		Effort (hours)		Temperature (°C)	Squawfish		Salmonids	Game fish	Other
		Hook and line	Electro-fishing		<275 mm	≥275 mm			
5/24-5/30	(22)	0	0	-	-	-	-	-	-
5/31-6/6	(23)	0.8	0	13	5	1	0	1	5
6/7-6/13	(24)	0.5	0.3	14	14	18	1[1]	4	235
6/14-6/20	(25)	1.3	0.5	14	6	13	0	5	95
6/21-6/27	(26)	0	0.2	16	3	7	0	4	154
6/28-7/4	(27)	0	0.	[illegible]	5	0	0	5	36
7/5-7/11	(28)	0	0	-	-	-	-	-	-
7/12-7/18	(29)	0	0.2	20	0	1	0	1	5
Total		2.6	1.3	NA	28	40	1	15[2]	530[2]

[1] 6/10/93; one juvenile salmonid (rainbow trout or steelhead) captured; had adipose fin; swam away immediately upon release.
[2] All game and non-game fish were released in good condition. See Table F-4 in text for species composition.

Appendix Table F-1.4. Results of sampling efforts in the **Potlatch River**, May-June, 1993.

Date (Statistical week)		Effort (hours)		Temperature (°C)	Squawfish		Salmonids	Game fish	Other
		Hook and line	Electro-fishing		<275 mm	≥275 mm			
5/24-5/30	(22)	1.5	0	18	0	0	0	0	0
5/31-6/6	(23)	2.0	0	16	0	1	0	0	0
6/7-6/13	(24)	0.8	0	16	0	0	0	0	0
6/14-6/20	(25)	1.0	0.8	18	1	0	0	10	48
6/21-6/27	(26)	2.5	0	17	0	1	0	5	0
6/28-7/4	(27)	4.5	0.1	9	0	2	0	9	4
7/5-7/11	(28)	1.4	0	21	0	3	0	0	0
7/12-7/18	(29)	1.5	0	-	-	1	-	-	-
Total		15.2	0.9	NA	1	8	0	24[1]	52[1]

[1] All incidentally captured game and non-game fish were released in good condition. See **Table F-4** in text for species composition.

Appendix Table F-1.5. Results of sampling efforts in **Lapwai Creek**, May-June, 1993.

Date (Statistical week)		Effort (hours)		Temperature (°C)	Squawfish		Salmonids	Game fish	Other
		Hook and line	Electro-fishing		<275 mm	≥275 mm			
5/24-5/30	(22)	0.5	0	16	0	0	0	0	0
5/31-6/6	(23)	3.0	0	17	0	1	0	0	0
6/7-6/13	(24)	1.3	0.4	15	6	10	0	0	0
6/14-6/20	(25)	1.0	0	16	0	0	0	2	1
6/21-6/27	(26)	1.5	0.5	12	11	4	0	6	27
6/28-7/4	(27)	1.5	0.3	18	22	14	0	3	12
7/5-7/11	(28)	0	0	-	-	-	-	-	-
7/12-7/18	(29)	0	0.3	20	0	0	0	3	8
Total		8.8	1.5	NA	39	29	0	14[1]	48[1]

[1] All incidentally captured game and non-game fish were released in good condition. See **Table F-4** in text for species composition.

Appendix Table F-1.6. Length, weight and sexual maturity data of northern squawfish captured in **the Tucannon River.**

	June		July	
	Females	Males	Females	Males
Sample size	16	12	1	2
Mean length (mm)	341	287		269
Range (mm)	292-483	240-318	270	252-285
Mean weight (g)	515	247		178
Range (g)	250-1550	120-400	200	115-240
Stage of maturity **(%)**				
Undeveloped		17		50
Developing	94	66	100	50
Ripe	6	17		
Spent				

Appendix Table F-1.7. Length, weight and sexual maturity data of northern squawfish captured in **Potlatch River.**

	June		July	
	Females	Males	Females	**Males**
Sample size	2	2	4	**0**
Mean length (mm)	381	389	380	
Range (mm)	355-407	358-420	335-425	
Mean weight (g)	640	585	511	
Range (g)	550-730	450-720	440-700	
Stage of maturity **(%)**				
Undeveloped		50		
Developing	100	50	50	
Ripe			50	
Spent				

Appendix Table F-1.8. Length, weight and sexual maturity data of northern squawfish captured in **Lapwai Creek.**

	June		July	
	Females	Males	Females	Males
Sample size	8	13	8	2
Mean length (mm)	330	269	352	268
Range (mm)	271-390	220-325	305-455	266-270
Mean weight (g)	459	269	352	268
Range (g)	255-760	110-400	3 10-980	200-255
Stage of maturity (%)				
Undeveloped		15	50	
Developing	100	85	37	100
Ripe			13	
Spent				

Report F - 302

REPORT G

Effectiveness of Predator Removal for Protecting Juvenile Fall Chinook Salmon Released From Bonneville Hatchery, 1993

Prepared by

Richard D. Ledgerwood
Earl M. Dawley
Lyle G. Gilbreath
Margaret A. Toner

Coastal Zone and Estuarine Studies Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Blvd. E., Seattle, Washington 98112-2097

Thomas P. Poe
National Biological Service, Columbia River Field Station
Star Route, Cook, Washington 98605-9701

Harold L. Hansen
Oregon Department of Fiih and Wildlife
Research and Development
17330 S.E. Evelyn St., Clackamas, Oregon 97015-9514

1993 Annual Report

CONTENTS

INTRODUCTION

Despite the almost universal belief that removal of northern squawfish (*Ptychocheilus oregonensis*) will increase survival of juvenile salmonids (*Oncorhynchus* spp.) in the Columbia River Basin (Figure 1), there has yet to be a direct demonstration of the benefit. In 1987, subyearling chinook salmon (0. *tshawytscha*) released along the shoreline just downstream from Bonneville Dam had poor survival relative to those released in midstream (Ledgerwood et al. 1990). Northern squawfish are known to inhabit protected shoreline areas (Petersen et al. 1990), and the poor survival rates of shoreline-released juvenile salmon was attributed, in part, to higher predation by northern squawfish.

To evaluate the advantage of releasing juvenile salmon in midstream Columbia River, the National Marine Fisheries Service (NMFS), in cooperation with the Oregon Department of Fish and Wildlife (ODFW), conducted salmon survival studies at Bonneville Hatchery from 1989 through 1993 (Ledgerwood et al. 1993, 1994). Each year, subyearling fall chinook salmon (upriver bright stock) were marked, then simultaneously released into Tanner Creek, the normal release site, which enters the Columbia River about 400 m downstream from the hatchery (Figure 2), and into the midstream Columbia River, lateral to the confluence of Tanner Creek. In 1989-1993, differences among seine recoveries of juvenile salmon in the estuary indicated that survival following the 157-km migration was dramatically better (65% better in 1989) for midstream Columbia River-release groups than for Tanner Creek-release groups.

In 1991, 1992, and 1993, with the help of personnel from the U.S. Fish and Wildlife Service (now the National Biological Service), the research was expanded to confirm the effectiveness of removing northern squawfish from the migration route of juvenile salmon from Bonneville Hatchery. Each year, two paired-groups of about 100,000 fish each were released into the midstream Columbia River and into Tanner Creek four days apart. On intervening nights, some northern squawfish in the vicinity of the hatchery release site were removed by electrofishing. Stomach contents of captured northern squawfish were examined for the presence of coded-wire tags (CWT) from study fish. In 1991 and 1992 it was apparent from CWT recoveries in the stomachs of northern squawfish that Tanner Creek-released juveniles were more vulnerable to predation than juveniles released in midstream (Ledgerwood et al. 1993, 1994). In addition, recoveries of juvenile salmon in the estuary indicated less benefit for release in midriver over Tanner Creek after northern squawfish removal each year. The decreased benefit was insignificant in 1991 and significant in 1992. These data lend credence to the hypothesis that predation on juvenile salmonids by northern squawfish may be decreased by removal of northern squawfish. The completed set of recovery data from juvenile and adult salmon will be necessary before final conclusions may be drawn.

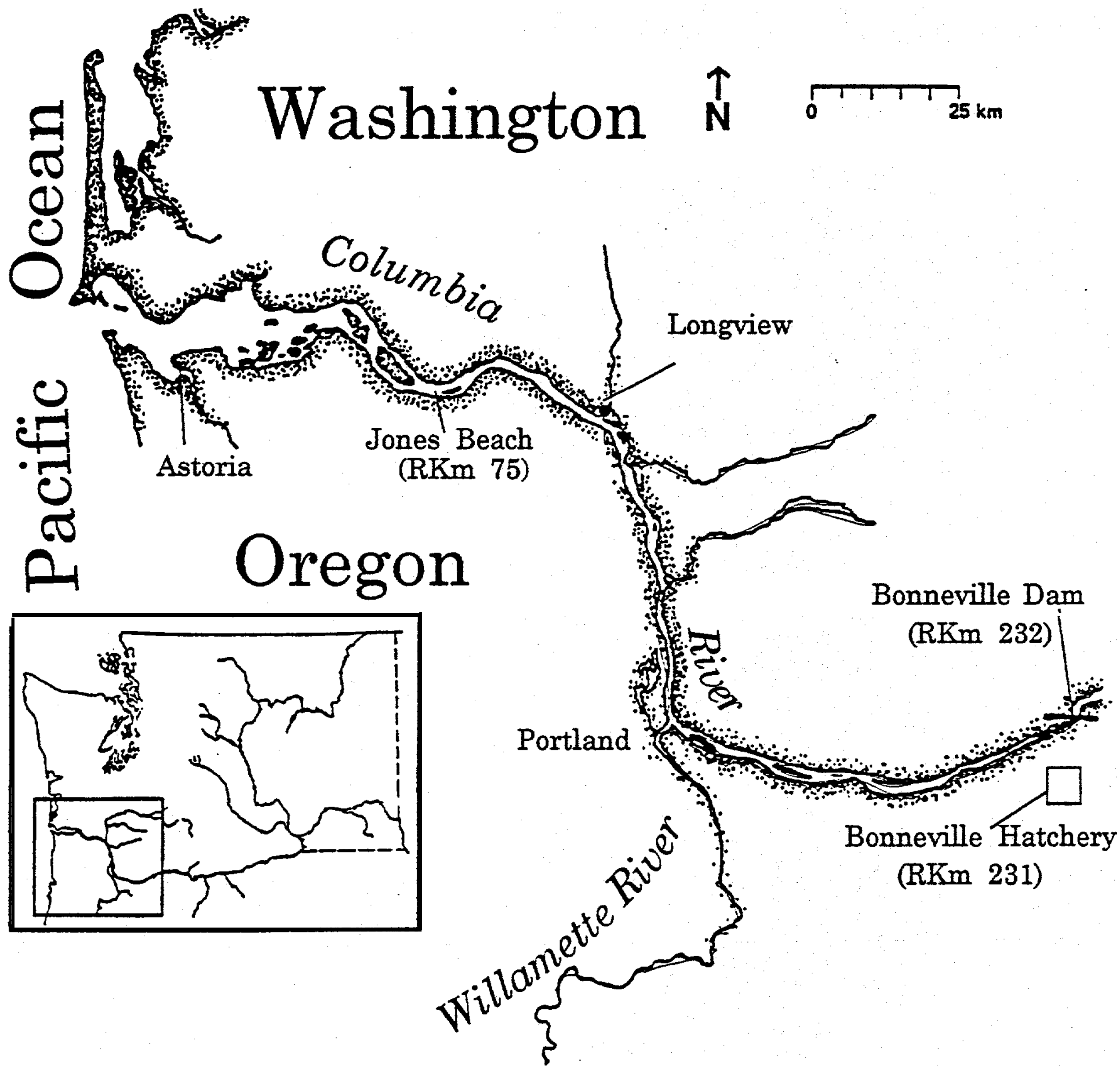


Figure 1. Columbia River Basin showing the study area.

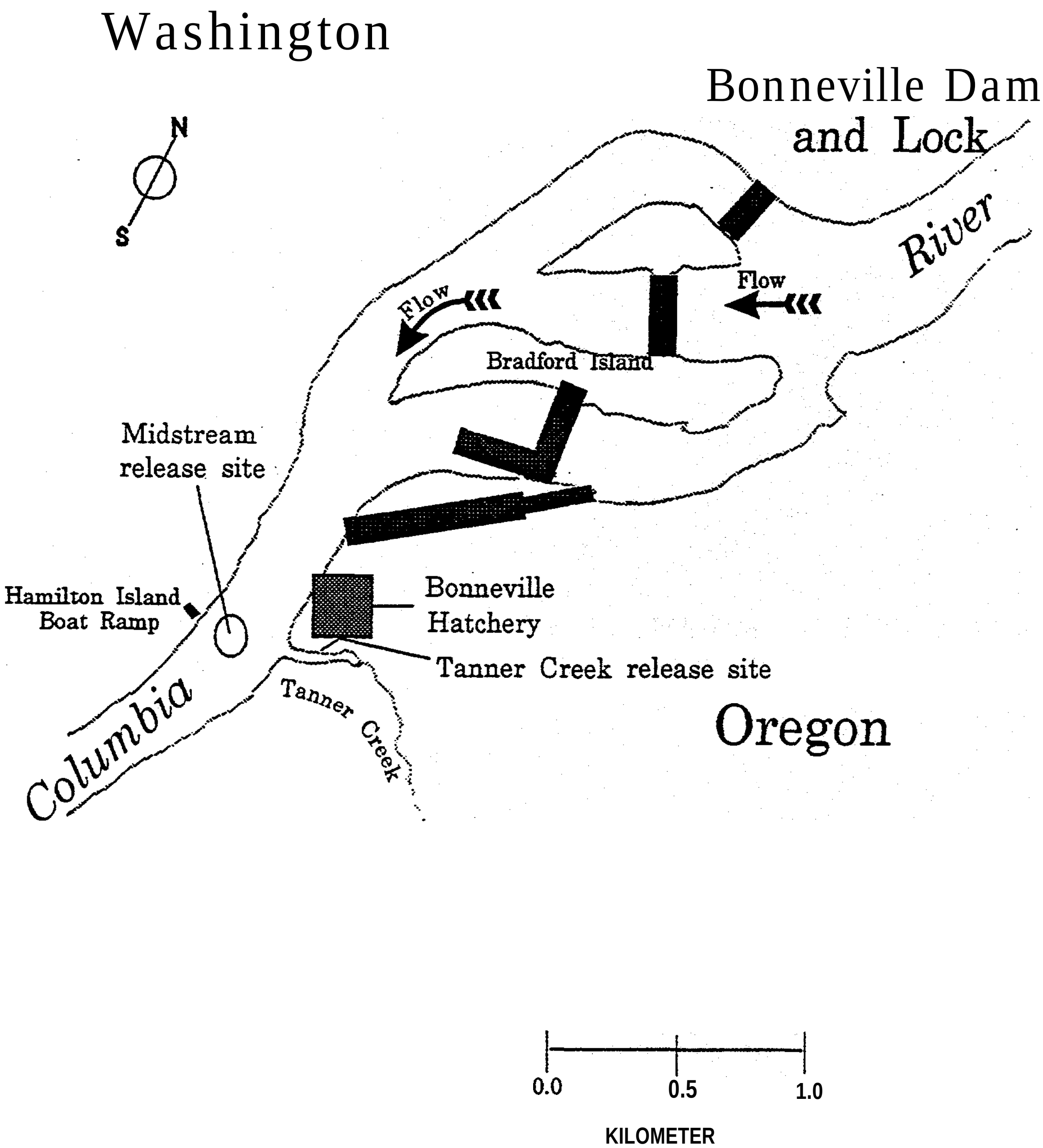


Figure 2. Release locations for subyearling chinook salmon, 1991-1993.

This report summarizes efforts and results of research conducted in 1993. The objectives were similar to those of 1991 and 1992: (1) assess survival differences for juvenile salmon before and after the removal of northern squawfish from Tanner Creek and adjacent shoreline areas of the Columbia River; (2) assess effectiveness of electrofishing to remove northern squawfish from the migration route of juvenile salmon in the vicinity of the hatchery release site; and (3) assess prey consumption by northern squawfish before and after large-scale predator removal efforts to determine the effects of predator size and density on the rate at which juvenile salmonids are consumed.

METHODS

Experimental Design

Prior to northern squawfish removal efforts, one uniquely marked group of 100,000 juvenile fall chinook salmon was released into Tanner Creek and another into the midstream Columbia River, lateral to the confluence of Tanner Creek. During the following four nights, extensive electrofishing was conducted to remove northern squawfish from Tanner Creek and from the adjacent shoreline areas of the Columbia River extending 1 km upstream and 6 km downstream from the release sites. Catch per unit effort (CPUE), size of fish removed, numbers of salmon ingested, and overall food consumption by northern squawfish were assessed to evaluate changes in the local population and impact on released salmon. Following the northern squawfish removal, a second pair of uniquely marked 100,000-fish groups was released at the two study sites. The second pair of releases was followed by another two nights of extensive electrofishing for northern squawfish to evaluate population changes in response to the reintroduction of juvenile salmon into the study area.

Purse and beach seining were conducted near the upper boundary of the Columbia River estuary at Jones Beach, River Kilometer (RKm) 75, to recover marked salmon. Recovery percentages of study fish were used to evaluate short-term survival differences between groups released at the two study sites before and after northern squawfish removal. Relative contributions of marked fish recovered in ocean and river fisheries and returning to the hatchery will provide a long-term evaluation for all release groups.

Test Fiih

Test fish were the progeny of fall chinook salmon (upriver bright stock) collected by ODFW personnel at Bonneville Hatchery. About 400,000 of these fish were reared at the hatchery for this study. At release, the mean size of these subyearling-age fish was 6.5 g (70.3 fish/lb), similar in size to the fish used in previous years, which ranged in size from 6.0 g to 7.4 g (75.7 to 61.0 fish/lb).

Marking Procedures

Test fish were marked by two 12-person crews on seven days (June 9-11 and June 14-17). About 60,000 fish were marked each day. Each marked group had unique. CWTs (Bergman et al. 1968). Cold brands (Mighell 1969) were applied to allow visual identification of fish from different treatment groups in samples seined from the estuary.

Logistics for marking fish were similar to those described by Ledgerwood et al. (1990). Two measures were taken to ensure that marked groups of fish did not differ in size, condition, rearing history, or mark quality. The four groups were marked simultaneously and differences in mark quality among groups were minimized by rotating mark codes among fish marking stations every two hours so that each marker and each station contributed equivalent numbers of marked fish to each treatment group. To assess quality control in the tagging process, samples of about 100 fish from each marked group were collected and checked for the presence of CWTs. These samples were taken periodically at the outfall pipes from the marking trailer. In addition, samples of about seven fish from each marked group were diverted into a separate holding pond at two-hour intervals throughout the marking day and held for a minimum of 30 days to determine tag loss and brand retention. Samples from each treatment were held in separate net pens. Estimates of tag loss ranged from 2.7% to 7.4% ($\bar{x}$ = 4.6, N = 1,966; Appendix Table G-1.1). Release numbers for each CWT group (treatment) were adjusted for estimated tag loss based on tag loss for the marked fish held a minimum of 30 days.

Release Locations and Procedures

Groups of marked fish were released into Tanner Creek (the normal hatchery release site) and into the midstream Columbia River, lateral to the confluence of Tanner Creek (Figure 2). The specific release locations and procedures were as follows:

1) Tanner Creek: Test fish were released using the normal hatchery procedure of drawing down the water in the rearing pond and crowding fish into an underground flume. The flume carried fish about 650 m to Tanner Creek, where they were free to migrate to its confluence with the Columbia -River, about 400 m downstream. At the confluence, fish were lateral to and about 150 m from the midstream Columbia River release site. Tanner Creek releases began at 8:30 p.m., about 1.5 hours prior to midstream releases, to provide extra time for fish traveling to the Columbia River.

2) Midstream Columbia River: Test fish were pumped through a 15-cm diameter hose into 4,000-L tanker trucks; three trucks were used on each release night. Each truck was loaded with about 34,000 fish to maintain transport densities of about 53 g fish/L water (0.5 lb/gal). The trucks were loaded aboard a barge at the boat launch on Hamilton Island with one truck per barge trip. At midstream, the fish were released into the river through a 3-m-long 15-cm diameter hose. Releases occurred between 10 p.m. and 11 p.m. at about RKm 232.

Northern Squawfish Removals

Two electrofishing boats were used to capture and remove northern squawfish. The bow platform of each boat was equipped with a pair of adjustable booms fitted with umbrella anode arrays. These arrays consisted of six stainless steel cables that were lowered into the water when fishing. All electrofishing was pulsed direct current using 60 pulses/second, 400-500 volts, and 4-5 amperes.

Electrofishing began at 3 a.m. on June 22, about six hours following the first pair of releases (Appendix Table G-2.1). On subsequent nights through June 25, electrofishing began at 9 p.m. and continued until 9 a.m. the next morning. Electrofishing was delayed the first night to allow test fish to disperse following release. Eight areas located between RKm 232 and RKm 225 were electrofished — one in lower Tanner Creek, and seven others in nearshore areas in the Columbia River (Figure 3)[1]. Each area was electrofished at least twice for about 30 minutes during each electrofishing period. Though transects on both the Oregon and Washington side of the Columbia River were electrofished, efforts were more concentrated in transect areas closest to the release locations.

Northern squawfish, stunned from electrofishing, generally came to the water surface and were collected with a dip net; some stunned fish were lost in the swift currents. Netted fish were placed in a lethal solution of tricaine methanesulfonate (MS-222) and within about 40 minutes of capture were taken to a processing station on shore where weight (g), fork length (mm), sex, and state of sexual maturity were recorded for each fish. The digestive tract (esophagus to anus) was removed from each fish, placed in a plastic bag, and frozen for later analysis.

In the laboratory, frozen digestive tracts were thawed and prepared for analysis using a digestive enzyme solution (pancreatin) to dissolve flesh, but leave intact diagnostic bones and CWTs from ingested fish (Petersen et al. 1990). The 2% (by weight) pancreatin solution, prepared using lukewarm tap water, also contained 1% sodium sulfide. This solution was added to the plastic bags containing the digestive tracts; the bags were then placed in a 40°C desiccating oven for 24 hours. The stainless steel CWTs, having a greater density than bone, sank to the bottom after agitation of the digested sample, and were removed. In addition, these samples were checked for missed CWTs using an electronic tag detector. CWTs were decoded using a compound microscope (Appendix Table G-2.2). The solid contents of the bags were then rinsed through a 425-μm sieve using tap water. A compound microscope and forceps were used to remove diagnostic bones (primarily cleithra, dentaries, and opercles) from the samples (Hansel et al. 1988). Diagnostic bones were identified and paired to enumerate salmonids and other prey consumed.

---

[1] A ninth transect area (W4) located on the Washington shore was fished in previous years, but was dropped from the sampling scheme in 1993.

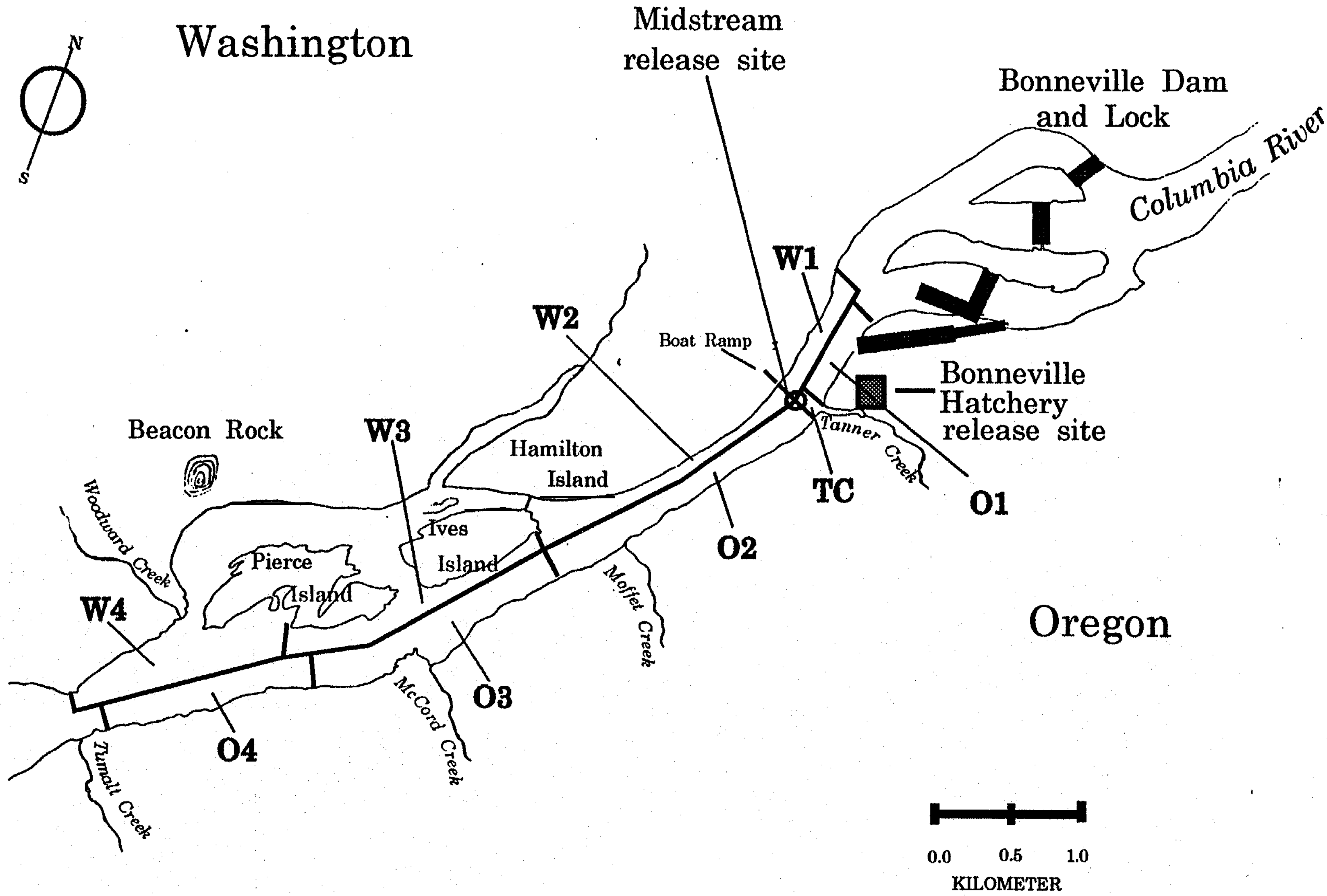


Figure 3. Electrofishing areas in Tanner Creek and adjacent shoreline areas of the Columbia River, 1991-1993.

Sampling Juvenile Salmon at Jones Beach

Short-term relative survival differences among release groups of juvenile salmon were derived from percentage differences of tagged fish recovered near the upper boundary of the Columbia River estuary at Jones Beach (Figure 4). Recovery methods and sampling site were described by Dawley et al. (1985, 1988). In addition to determining recovery differences, captured fish were observed for differences in descaling, injuries, size, and migration behavior.

During the period from June 25 through July 12, sampling was conducted by two crews working seven days per week for eight to 12 hours per day, beginning at sunrise (Appendix Table G-1.2). Both purse seines (midstream) and beach seines (Oregon shore) were used to determine whether study fish were more abundant in midstream or near shore and to maximize effort using the gear type that captured the greatest numbers of study fish.

All captured fish were processed aboard the purse seine vessels. The catch from each set was anesthetized and enumerated by species. Numbers of dead, injured, or descaled salmonids were recorded and subyearling chinook salmon were examined for excised adipose fins and brands. Marked fish were separated for further processing, while unmarked fish were returned to the river immediately after counting, evaluation, and recovery from anesthesia. Descaling was judged rapidly while counting and separating study fish from non-study fish. Fish were classified as descaled when 25% or more of their scales on one side were missing.

Freeze brands were used to identify study fish; from these fish, we collected CWTs, obtained biological samples, compared fish size among treatment groups, and adjusted the daily sampling effort to attain the desired minimum sample size of 0.5% of the number of fish released. Brand information and biological and associated sampling data (e.g., date, vessel code, gear code, set number, time of examination, fork length, and descaling) were immediately entered into a computer data base and printed. Fork lengths of marked fish were recorded to the nearest mm. All branded fish (including those with illegible brands) were sacrificed to obtain CWTs, which identified treatment group and day of release.

Branded fish were processed in lots, segregated by recovery day and capture site. An aqueous solution of 40% potassium hydroxide was used to dissolve the heads for ease in extracting CWTs. All CWTs were decoded and later verified; additional details of tag processing followed the methods described by Ledgerwood et al. (1990).

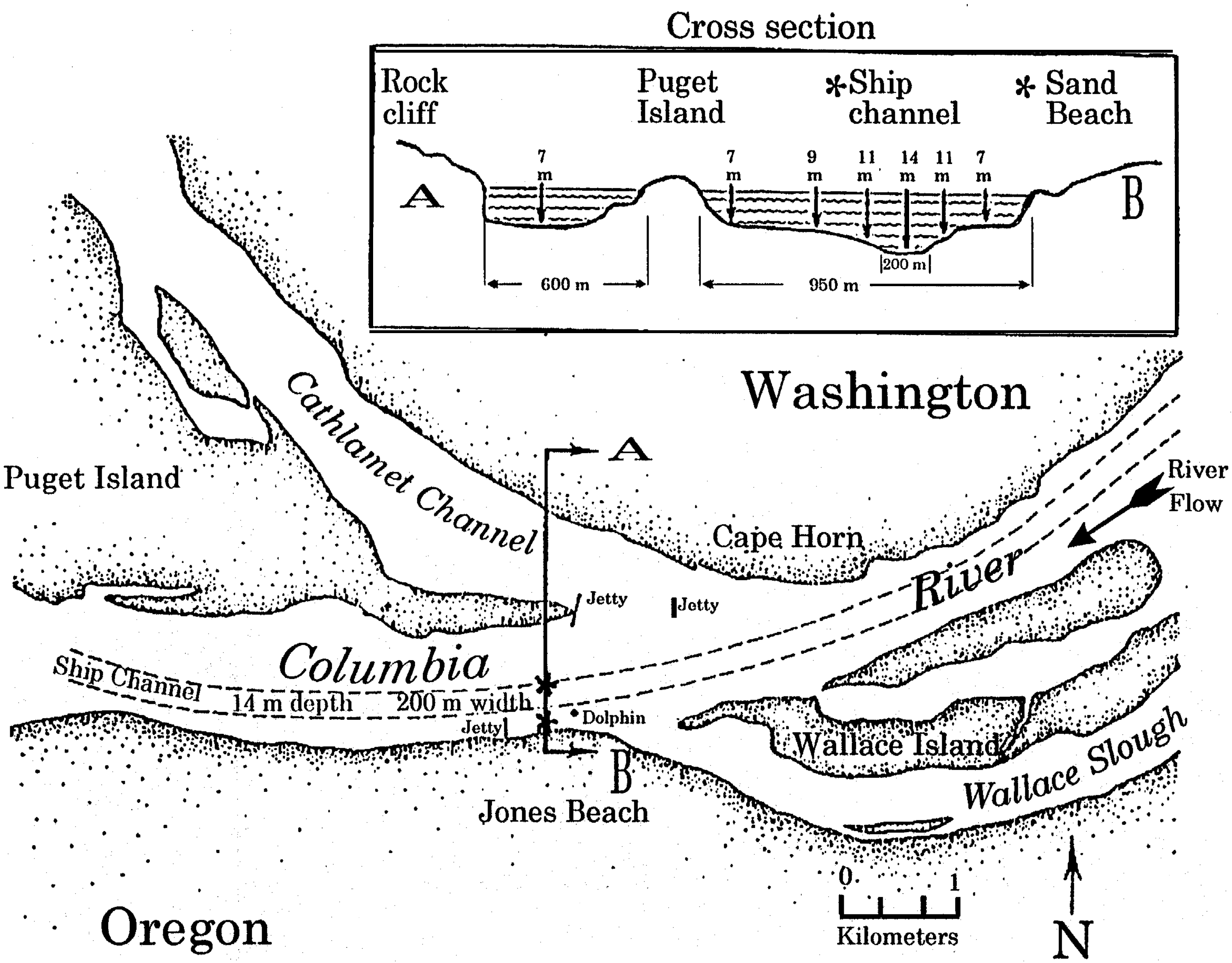


Figure 4. Jones Beach, Columbia River, sampling sites. The beach and purse seining areas are denoted by asterisks.

Purse seine data obtained from June 25 to July 12 were adjusted for effort to obtain a standardized catch per day per group. Beach seine catch data were not similarly adjusted due to low sampling effort. The following formula was used to standardize purse seine data to a 12-set-per-day effort for each marked group:

$$A_i = N_i (S \div P_i)$$

where:

A_i = Standardized purse seine catch on day i;
N_i = Actual purse seine catch on day i;
S = Constant (weighted daily average number of purse seine sets (12) during the sampling period); and
P_i = Actual number of purse seine sets on day i.

Dates of median recovery for each marked fish group were determined using the standardized purse seine. Movement rates for each CWT group were calculated as the distance from the midstream Columbia River release site (RKm 232) to Jones Beach (RKm 75) divided by the travel time (in days) from release date to the date of the median fish recovery.

Statistical Analyses

The hypothesis that recovery ratios at Jones Beach were equal for fish released into Tanner Creek and the midstream Columbia River was tested using a paired difference z-test. The hypothesis that different marked groups, released the same day, had equal probability of capture through time was tested using chi-square goodness of fit (Zar 1974).

RESULTS

In 1993, a total of 399,040 subyearling chinook salmon were marked with freeze brands, CWTs, and excision of the adipose fin before release (Table G-l). Between the two release dates, 2,291 northern squawfish were captured and removed from the study area (Table G-2). An additional 575 northern squawfish were removed from the study area following the second release. We recovered 1,988 study fish in the estuary (ca. 0.6% of those released); most were midstream migrants captured with purse seines (Appendix Table G-l .3). Handling mortality for all captured juvenile salmon was less than 0.5 % and the descaling rate was less than 2%. Five descaled study fish were captured at Jones Beach, too few for meaningful among-treatment comparison.

Table G-l. Summary of Tanner Creek and midstream Columbia River releases of marked subyearling chinook salmon, 1993.

Marking dates	Release date	Brand[a]	Number released: Total[b]	Untagged[c]	Tagged[d]	wire tag code (AG D1 D2)[e]
Tanner Creek releases						
9-17 June	21 June	RD Z2	99,702	3,689	96,013	23 30 21
9-17 June	25 June	LD Z2	99,272	7,346	91,926	23 30 22
Midstream Columbia River releases						
9-17 June	21 June	RD Z1	99,516	4,578	94,938	23 30 23
9-17 June	25 June	LD Z1	100,550	2,715	97,835	23 30 24
		Total	399,040	18,328	380,712	

[a] Brand codes: first and second characters, RD = right dorsal position; third character is the brand symbol; fourth character is brand rotation where 1 = symbol in the upright position and 2 = symbol rotated clockwise 90" from upright position.

[b] Total fish marked; branded, tagged, and adipose fin clipped (less observed pre-release mortality and fish retained for tag loss evaluation).

[c] Estimated number of fish released without coded-wire tags (Appendix Table G-l. 1).

[d] Estimated number of fish released with coded-wire tags.

[e] CWT code key: AG D1 D2 = Agency code, Data 1 code, Data 2 code.

Table G-2. Number of northern squawfish removed by day (all electrofishing sites) and number of coded-wire tags recovered in digestive tracts of northern squawfish, 1993.

Electrofishing date (time)	Northern sauawfish removed: Time shocker on (sec)	Total catch	CPUE[b]	Mean length (mm)	Mean weight (g)	CWTs recovered[a] Release site: Tanner[c] Creek	Mid-[d] stream
Data pertinent to first paired release							
22 June (0300-0900)	10,488	253	87	321	734	114	2
22-23 June (2100-0900)	18,988	872	165	306	412	41	1
23-24 June (2100-0900)	18,738	650	125	293	369	2	--
24-25 June (2100-0900)	18,471	516	101	300	385	--	--
Subtotal	66,685	2,291	119.5	305.0	475.0	157	3
Data pertinent to second paired release							
26-27 June (2100-0900)	18,272	346	68	287	341	--	--
27-28 June (2100-0900)	11,549	229	71	308	410	--	--
Subtotal	29,821	575	69.5	297.5	375.5	--	--
Totals	96,506	2,866	102.8	302.5	441.8	157	3

[a] CWT = coded-wire tag (Agency code/Data 1 code/Data 2 code). Number of CWTs recovered in the digestive tracts of northern squawfish represent a minimum number of juvenile salmon ingested.
[b] CPUE = catch per unit effort, number of fish caught per hour.
[c] CWT code = 23/30/21, released June 21.
[d] CWT code = 23/30/23, release June 21.

Northern Squawfish Removals

We captured and removed a total of 2,866 northern squawfish from the eight transect areas during about 27 hours (96,506 seconds) of electrofishing (Table G-2). Sixty-one percent (1,759) of those removed were caught in Tanner Creek or adjacent transect areas along the Oregon shore (01, 02, and 03) (Figure 5), similar to catch distributions in 1991 and 1992. During the June 22-25 electrofishing periods (following the June 21 release), catch rates of northern squawfish were higher (mean = 119.5 fish/hour) than during the June 26-28 electrofishing periods (following the June 25 release) (mean = 69.5 fish/hour). There was little indication that northern squawfish recolonized the Tanner Creek or adjacent transect areas immediately after release of juvenile salmon from Bonneville Hatchery (Table 3). The mean fork lengths (302 mm) and weights (442 g) of northern squawfish were fairly consistent throughout the removal periods and considerably less than for northern squawfish captured during 1991 (means 344 mm and 606 g), but similar in size to those captured during 1992 (means 303 mm and 430 g; Figure 6). The number of CWTs recovered in the digestive tracts of northern squawfish (representing ingested juvenile salmon) diminished dramatically following the first electrofishing period. Of the 167 CWTs recovered from the digestive tracts of northern squawfish (Appendix Table G-2.2), 94% were from study fish and all of those except three were from study fish released June 21 into Tanner Creek; the exceptions were study fish released June 21 into the midstream Columbia River. The CPUE for northern squawfish was highest in the Tanner Creek transect area, and 10% of the CWTs from study fish were recovered from those northern squawfish (Table G-3). Although the percentage of CWTs recovered in the Tanner Creek transect area was low, it should be noted that this transect area was considerably smaller than the other transect areas and consequently received correspondingly less electrofishing effort. Also, due to a drop in tailwater elevation at Bonneville Dam on June 26, it was impossible to electrofish within Tanner Creek following the June 25 release of study fish.

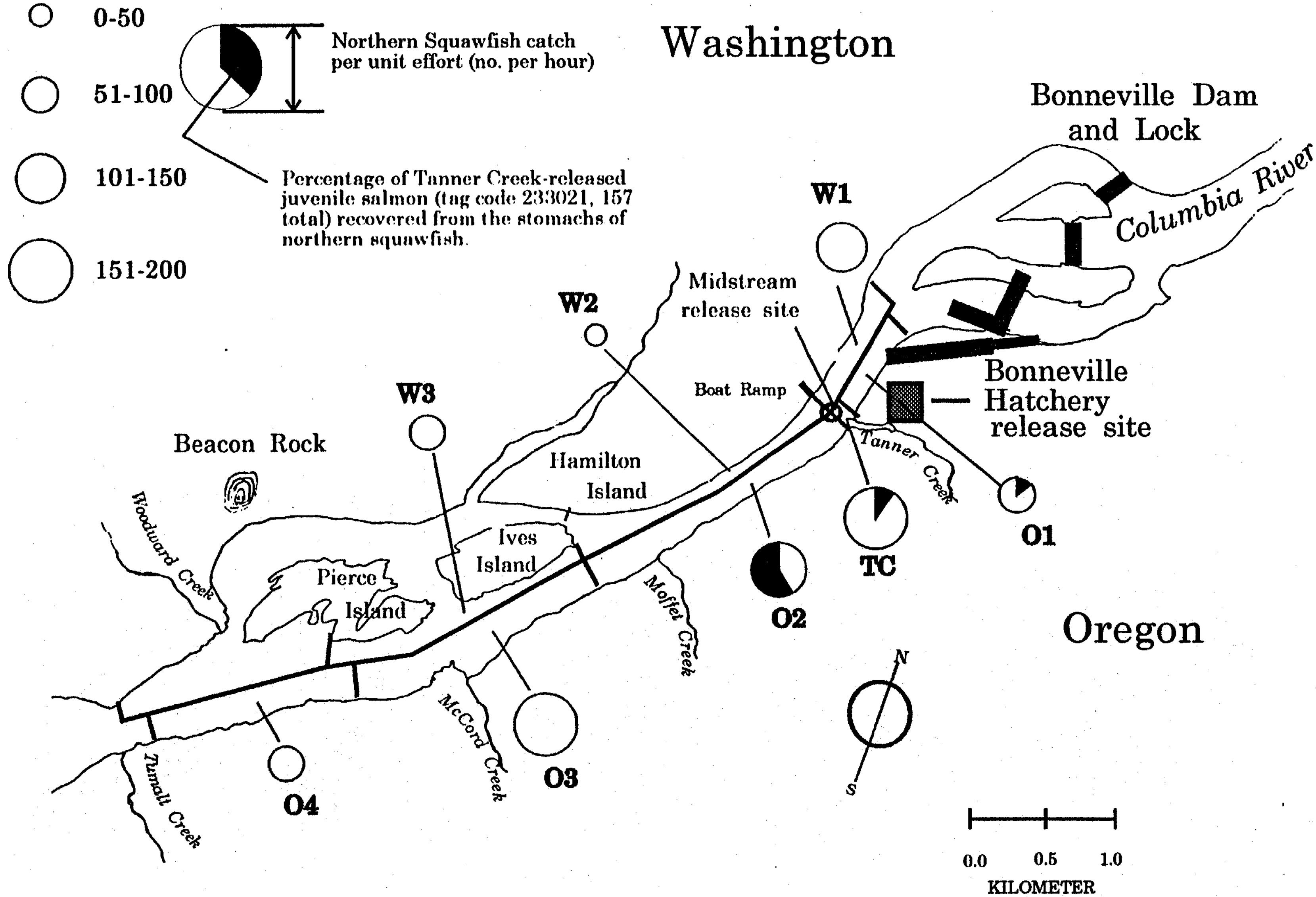


Figure 5. The study area showing the northern squawfish catch per unit effort at each electrofishing transect area and proportion of tags (representing ingested juvenile salmon) from the 21 June Tanner Creek release group recovered in those northern squawfish, 1993.

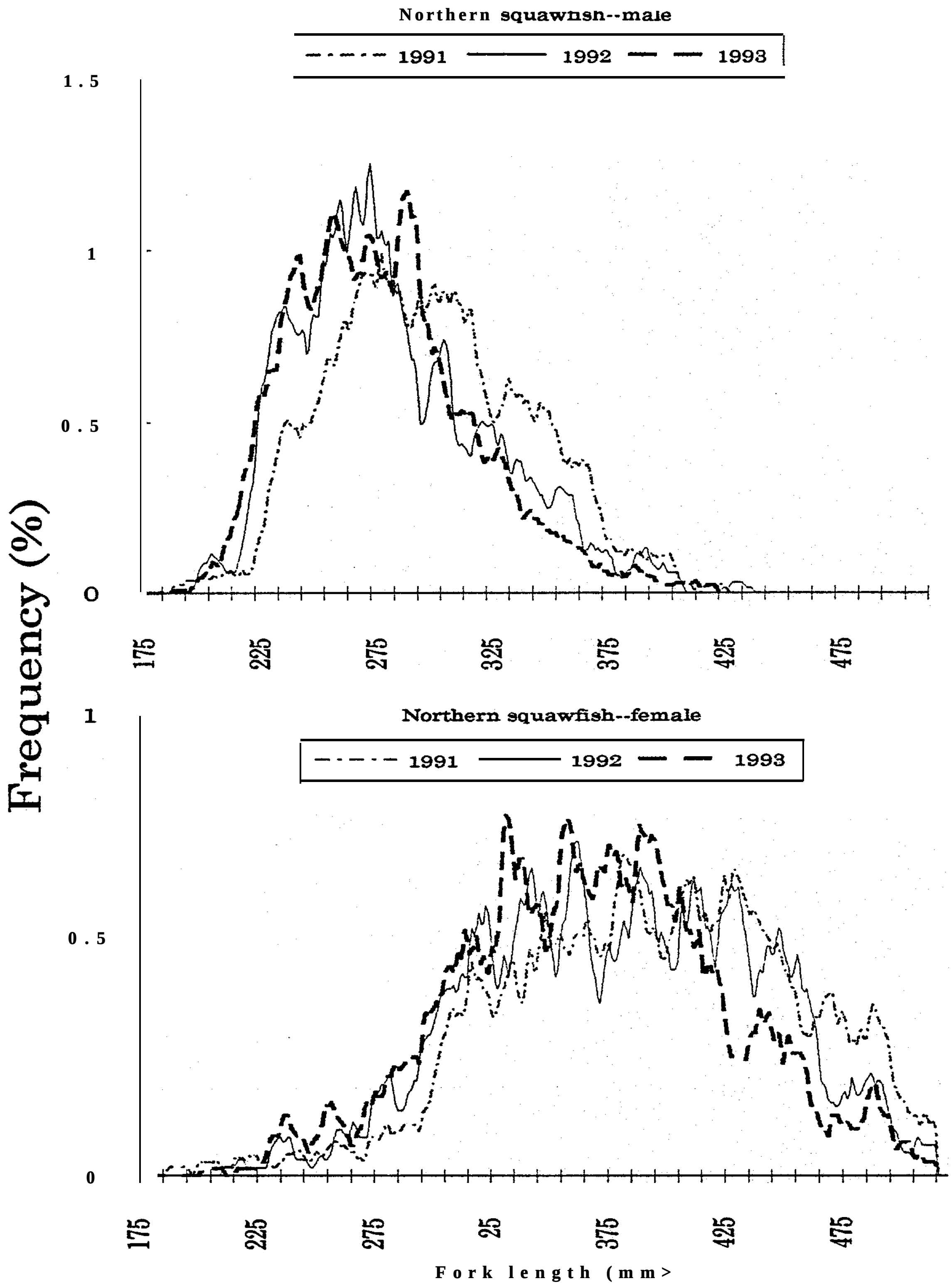


Figure 6. Fork length distributions of northern squawfish removed from the study area by electrofishing, 1991, 1992, and 1993.

Juvenile Salmon Catch Patterns and Movement Rates

There was no evidence from the Jones Beach recovery data to suggest non-homogeneity between treatment recovery distributions of study fish groups released on the same day (α = 0.05; Appendix G-3); thus the recovery data were standardized to a constant daily effort to determine the date of median fish recovery and to calculate movement rates (Appendix Table G-l .3). Temporal catch distributions of each release group are presented in Figure 7.

Movement rates of study fish between the release site and Jones Beach ranged from 19.6 km/day to 22.4 km/day, similar to movement rates in 1991 and 1992, but faster than movement rates in 1989 or 1990 (Table G-4). Movement rates of fish from the second release groups were slightly slower than those of the first release groups, due perhaps in part to decreased river flow following the second release (Figure 8).

Comparisons of fork length distributions of study fish at release to those captured at Jones Beach suggest that all groups grew about 1 mm per day during the migration period (Figures 9-10). At recovery there were no apparent differences in daily mean lengths among treatment groups (Figure 11). Generally, fish from both pairs of releases showed little change in mean length during the recovery period.

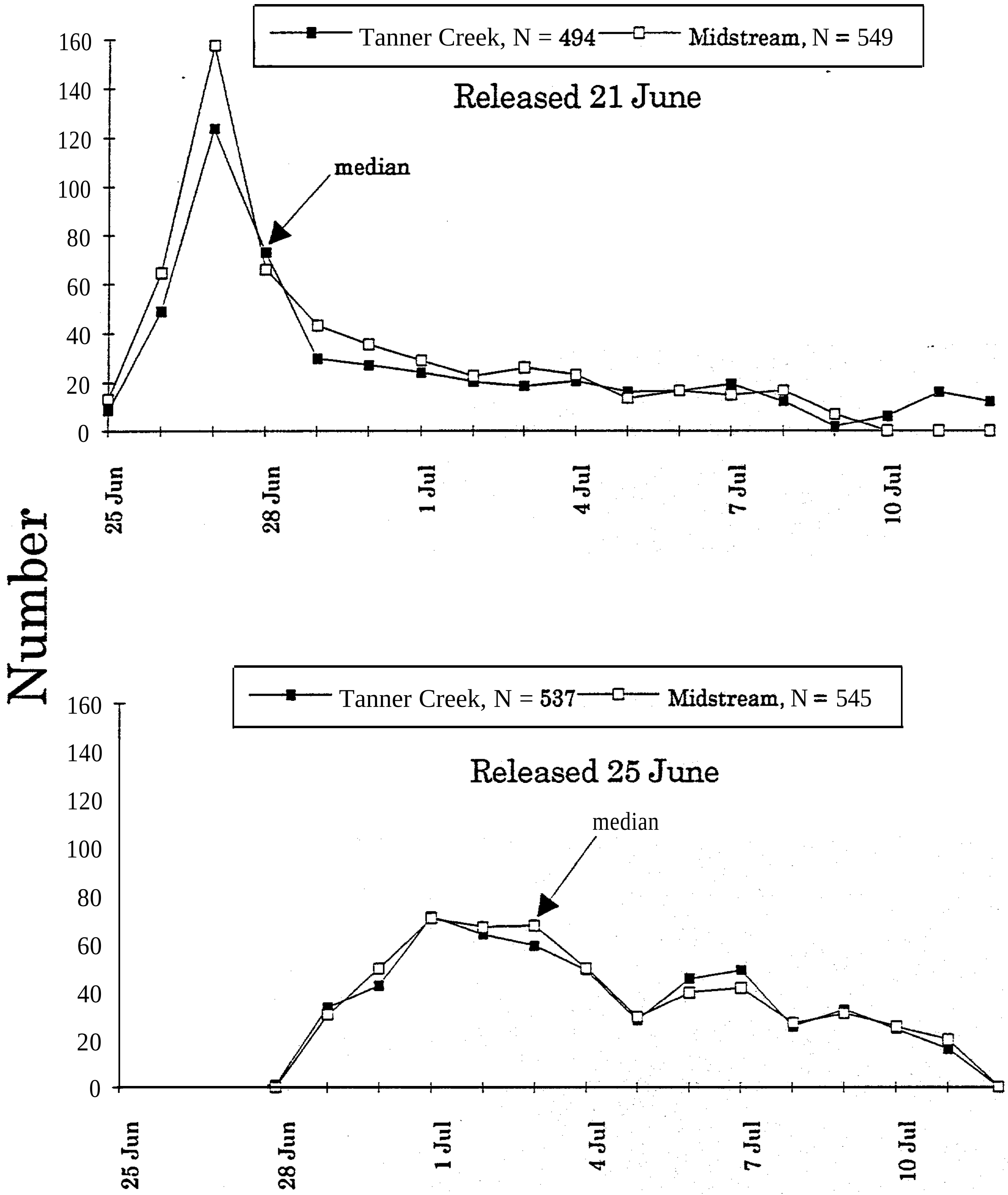


Figure 7. Daily recoveries of test fish at Jones Beach (standardized for effort) comparing midstream Columbia River to Tanner Creek release-groups, 1993.

Table G-4. Movement rates to Jones Beach for marked groups of subyearling chinook salmon released in Tanner Creek and in midstream Columbia River, 1989, 1990, 1991, 1992, and 1993.

Release date	Movement rate (km/day) Midstream Columbia	Tanner Creek	Mean FL (mm)[b]	Flow (kft^3/sec) At release[c]	At median[d]
29 June 1989	10.4	9.8	101	142	113
1 July 1990	12.1	12.1	91	247	190
24 June 1991	15.7	17.4	92	215	262
28 June 1991	22.4	22.4	92	272	258
15 June 1992	17.4	17.4	95	191	198
19 June 1992	19.6	19.6	94	207	186
21 June 1993	22.4	22.4	91	199	186
25 June 1993	19.6	19.6	92	202	175

[a] Movement rate = distance from the midstream Columbia River release site (RKm 232) to recovery site (RKm 75) ÷ time in days from release to median fish recovery. Median fish recovery based on standardized daily effort (Appendix Table G-l .3).

[b] Mean fork length of fish recovered at Jones Beach.

[c] Daily average flow at Bonneville Dam on the day that fish were released.

[d] Four-day average flow at Bonneville Dam within 2 days before and after the date that the median fish was captured; by convention, English units were used for river flow volumes (kft^3/sec = 1,000 ft^3/sec = 28.3 m^3/sec).

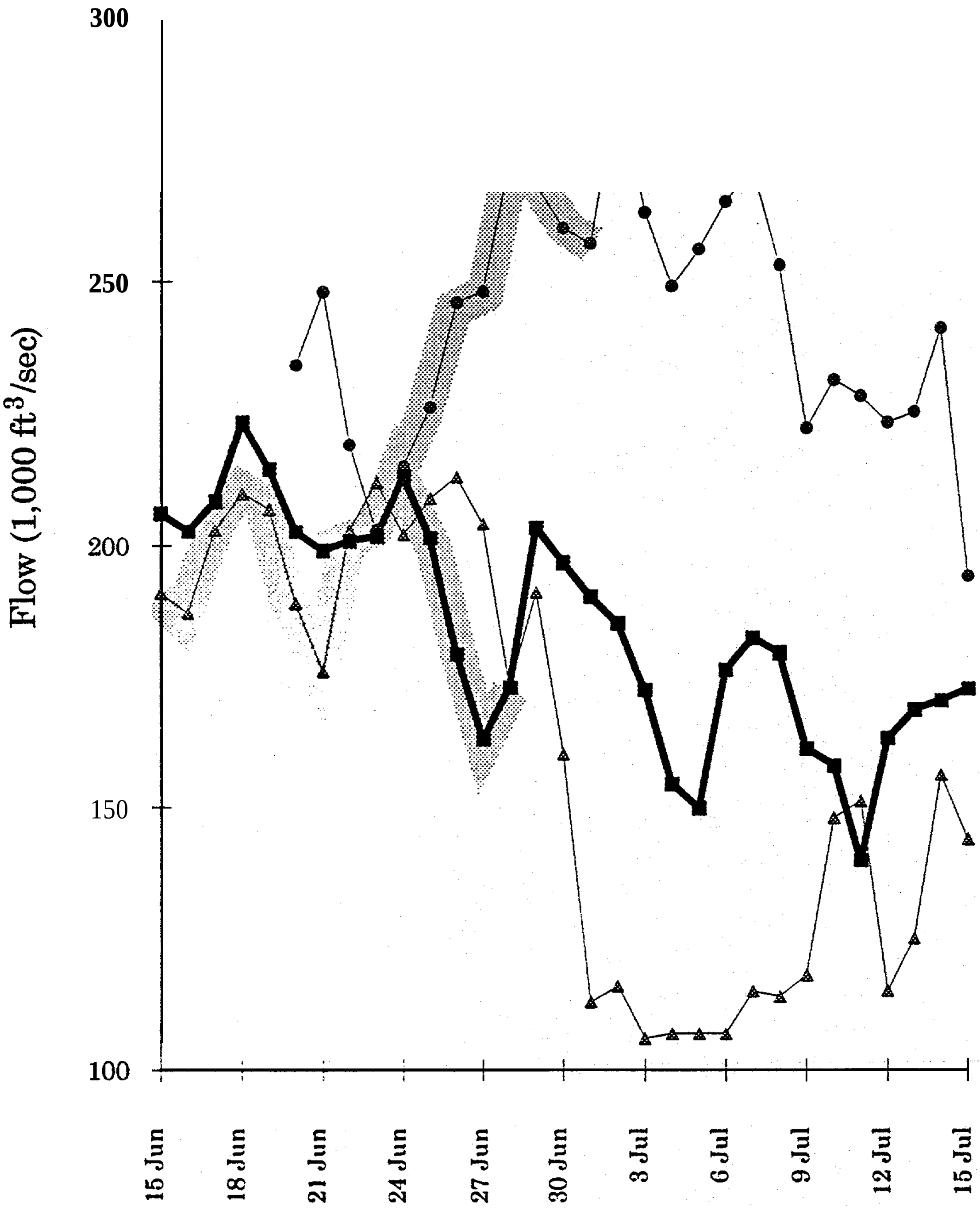


Figure 8. Daily mean flows of the Columbia River at Bonneville Dam during the estuarine **sampling periods,** 1991, 1992, and 1993; flow measurements provided by the U. S. Army Corps of Engineers, Portland, Oregon.

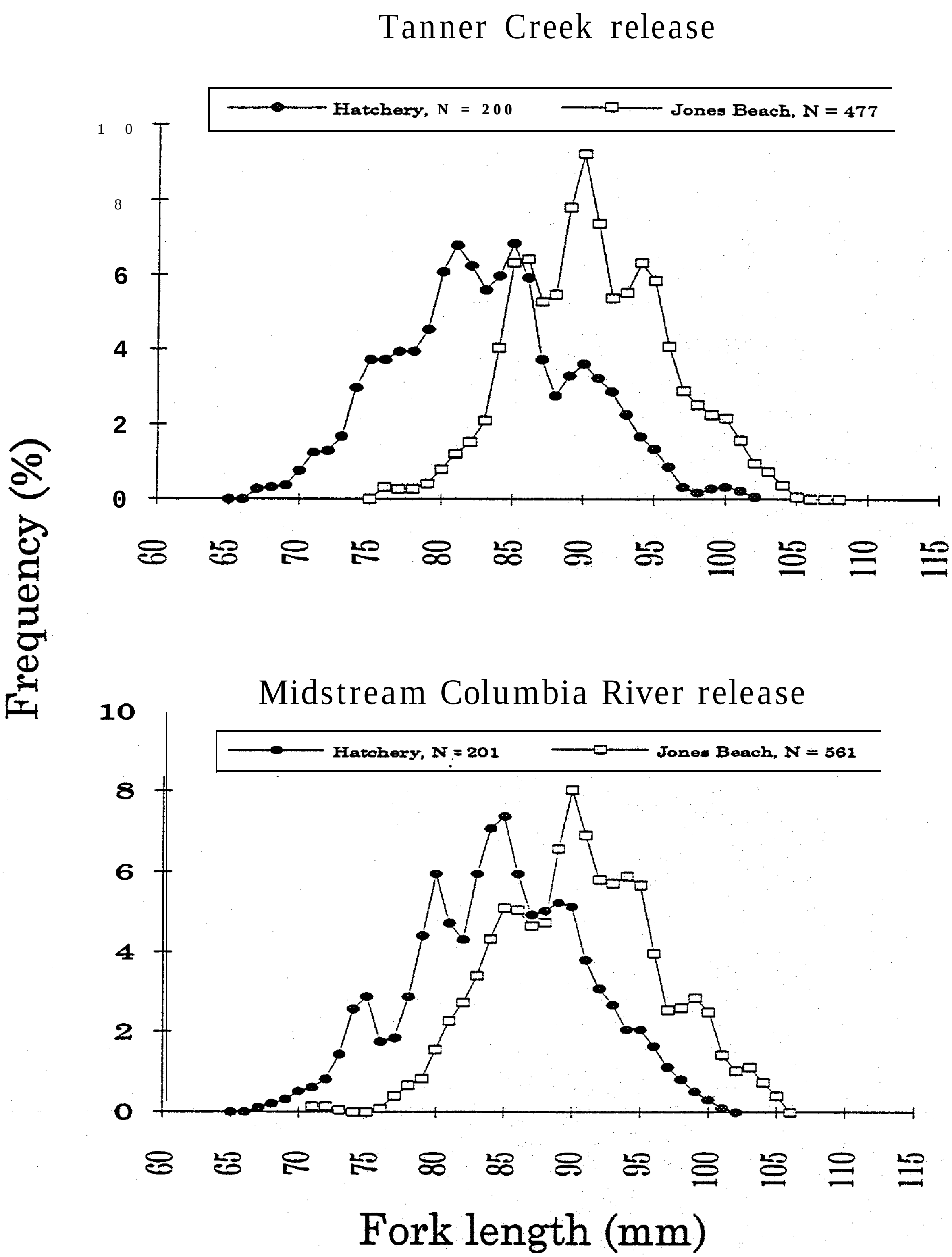


Figure 9. Fork length distributions of study fish at release and after recovery at Jones Beach for fish released on 21 June 1993.

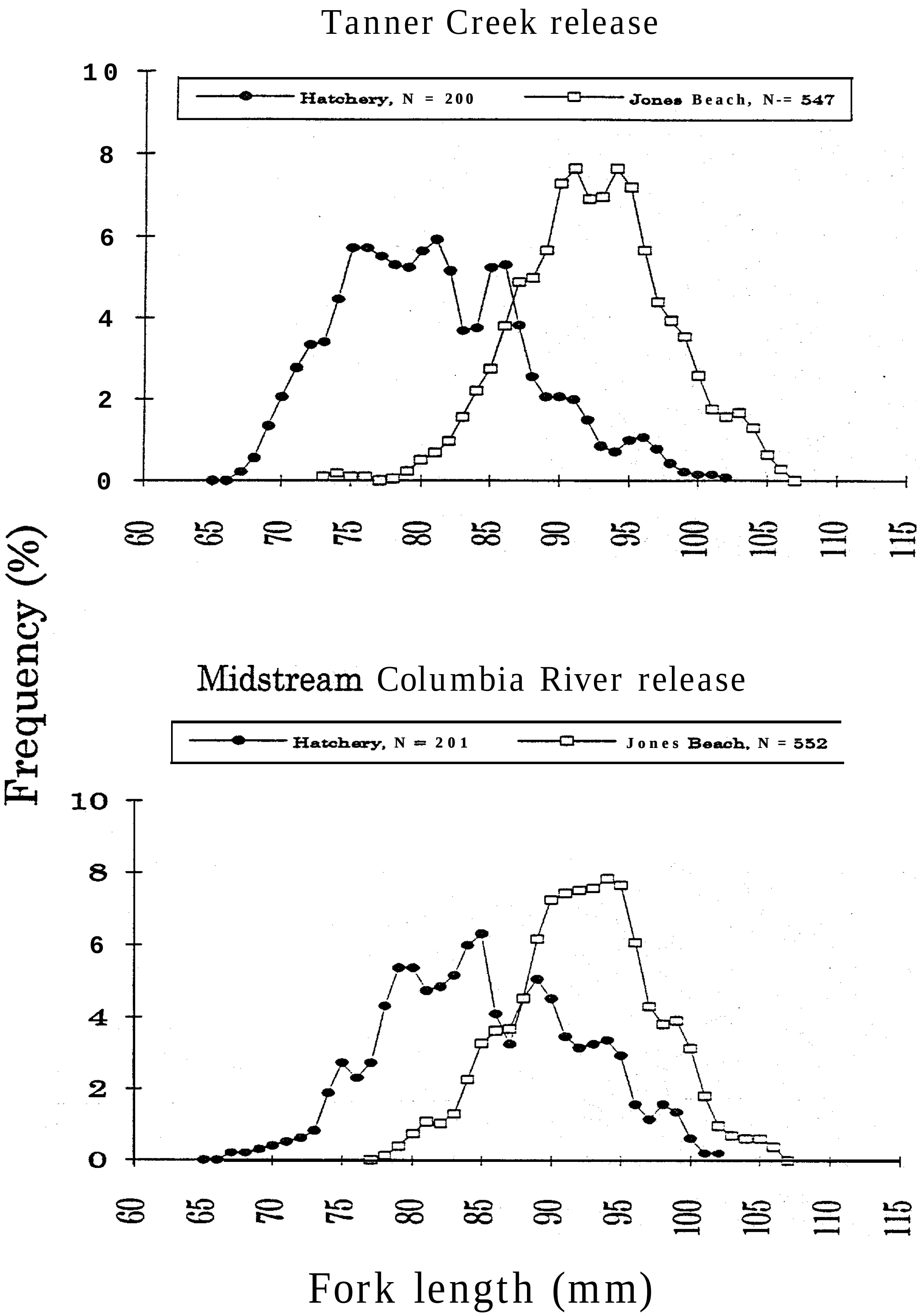


Figure 10. Fork length distributions of study fish at release and after recovery at Jones Beach; fish released on 25 June 1993.

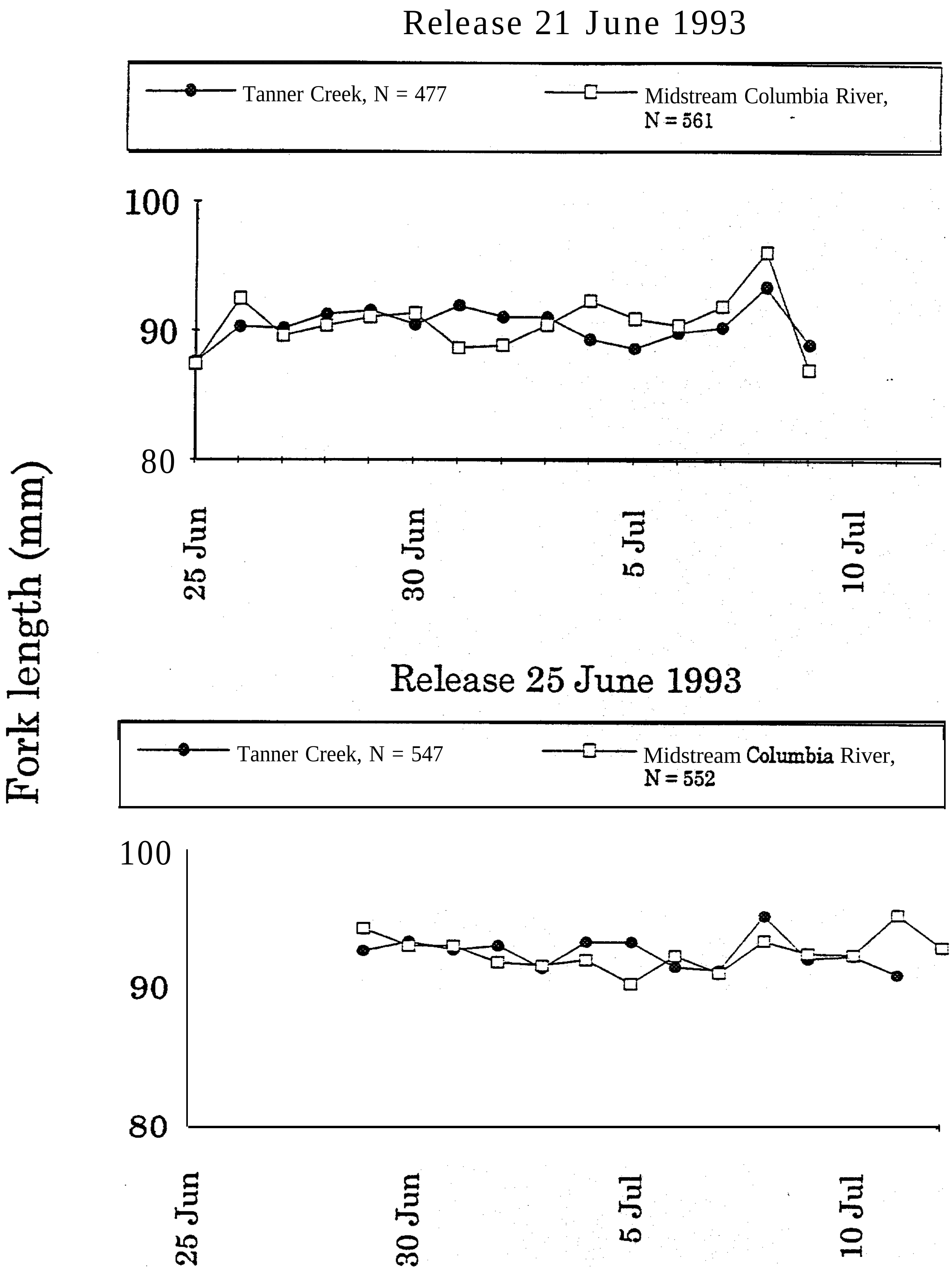


Figure Il. Daily mean fork lengths of subyearling chinook salmon recovered at Jones Beach, comparing midstream Columbia River to Tanner Creek release groups, 1993.

Juvenile Salmon Recovery Differences

Analysis of CWT-fish recoveries at Jones Beach (Appendix G-3) indicated that the recovery percentages for fish released into the midstream Columbia River were significantly higher ($P = 0.0023$) than for fish released into Tanner Creek for the first release group (0.64 % versus 0.60%). However, for the second pair of release groups, the differences in recovery percentages were reversed, but not significantly different ($P = 0.3120$), with Tanner Creek recoveries higher than midstream Columbia River recoveries (0.64% versus 0.60%, respectively). Although the relative recovery percentages of the two treatment groups changed between the two release dates (Figure 12), these percentages are not directly comparable because fish releases made on the two different dates were subject to different river conditions, which may affect both migration survival and sampling efficiency, and thus recovery. After the localized removal of northern squawfish, the difference in recovery percentages between the two release sites was reduced from 19.7% to -5.7% (Figure 12; Appendix G-3, Part lc); this 129% reduction in recovery differences ((19.7 - (-5.7) ÷ 19.7) * 100) was significant ($P = 0.0041$).

To further assess data consistency, we analyzed purse seine recoveries separate from total recoveries (Appendix Table G-l .3, Appendix G-3). Conclusions regarding differences among recovery ratios derived from the purse seine data were the same as those reached with the total catch data; recoveries of study fish released from the midstream Columbia River were significantly higher ($P < 0.01$) than those for fish released into Tanner Creek for the first release pair and insignificant ($P = 0.31$) for the second release pair. Similarly, there was a significant change ($P < 0.01$) in the difference between recovery percentages following removal of northern squawfish. Beach seine recoveries separate from total recoveries were too few as a data subset for meaningful analysis (less than 2%).

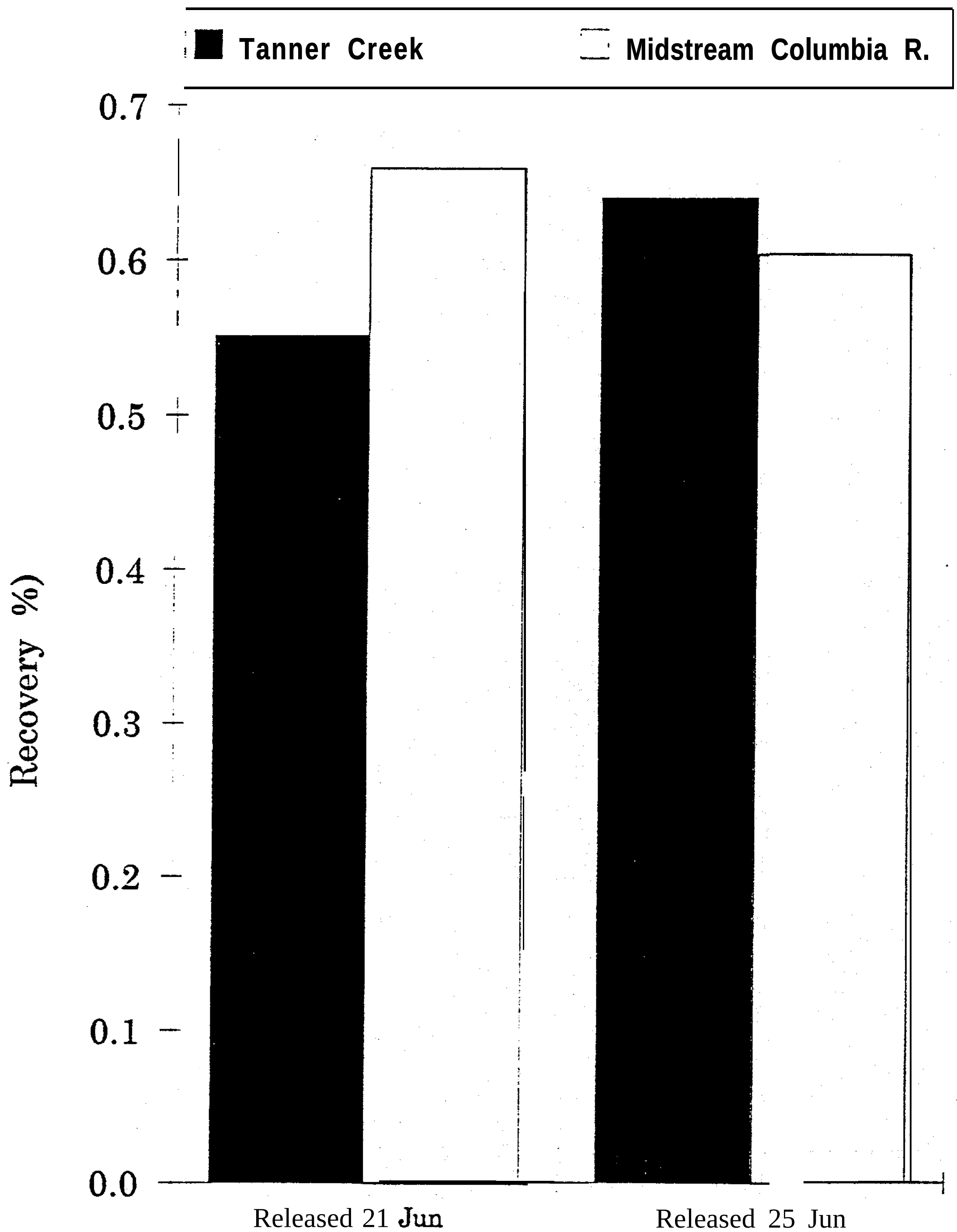


Figure 12. Mean recovery percentages comparing midstream Columbia River to Tanner Creek release groups, 1993. Northern squawfish were removed by electrofishing between the two release dates. Recovery rate for the midstream release group was significantly higher ($P < 0.05$) than for the Tanner Creek release group on 21 June.

DISCUSSION

In 1993, for the first time in eight comparisons over a five-year period, the recovery percentage in the estuary of a marked group of subyearling chinook salmon released into Tanner Creek was higher than the recovery percentage of a similar marked group released into the midstream Columbia River (Table G-5). This exception occurred following electrofishing to remove northern squawfish from the presumed migration route of the Tanner Creek released fish. In all previous marked-group comparisons, dating back to studies in 1989, the midstream Columbia River release groups had significantly higher ($P < 0.05$) recovery percentages after migration to the estuary than groups released directly from Bonneville Hatchery into Tanner Creek.

In 1993, also for the first time, the reduction in benefit for midstream Columbia River release following the electrofishing effort was significant ($P = 0.0041$). In 1991 and 1992, although the benefit for midstream release declined following electrofishing, there remained a significant benefit to releasing subyearling chinook salmon from Bonneville Hatchery at the midstream Columbia River site. We questioned whether the observed declines following electrofishing to remove northern squawfish during 1991 and 1992 were actually a result of electrofishing, or merely responses to changing river flow or other coincidental events occurring between the two release dates each year.

Based on results from studies conducted from 1991 through 1993, we believe that the effectiveness of localized predator removal in protecting juvenile salmon released from Bonneville Hatchery is affected by Columbia River flows at the time of test fish release, as well as the systemwide northern squawfish removal program (Willis and Nigro 1994). We speculate that higher river-flow at the time of release allowed for faster downstream dispersal of Tanner Creek-released fish, resulting in less predation by northern squawfish in the Tanner Creek-Columbia River confluence area and increased survival. We further speculate that the local population of northern squawfish was lower in 1993 than in earlier years of study as a result of the basinwide northern squawfish sport-reward fishery, and this reduced population was more effectively controlled by electrofishing. In total, about 200,000 northern squawfish were removed from the tailrace area of Bonneville Dam between 1991 and 1993 (S. Smith, WDFW, Pullman, pers. comm.).

Table G-5. Recovery percentages of tagged subyearling chinook salmon at Jones Beach for Tanner Creek and midstream Columbia River release groups, 1989, 1990, 1991, 1992, and 1993.

Release date	Midstream Columbia River[b]	Bonneville Hatchery at Tanner Creek”	Benefit? for midstream release (%)
29 June 1989	0.43	0.26	**65.4**[*d]
1 July 1990	0.42	0.30	40.0’
24 June 1991	0.37	0.30	**23.3**[*]
28 June 1991	0.39	0.33	**18.2**[*] post-removal’
15 June 1992	0.57	0.42	**35.7**[*]
19 June 1992	0.60	0.51	17.6’ post-removal
21 June 1993	0.66	0.55	20.0’
25 June 1993	0.60	0.64	-6.3 post-removal”

[a] The percent benefit for midstream Columbia River release (MC) over Tanner Creek release (TC) is calculated as: [(MC% recovery - TC% recovery) ÷ TC% recovery] X 100.

[b] Fish transported by truck and barged to the middle of the Columbia River adjacent to the confluence with Tanner Creek.

[c] Normal hatchery release site.

[d] * = significant difference in recovery percentages for fish released in midstream Columbia River or Tanner Creek ($P \leq 0.05$).

[e] Benefit for midstream release following 4 days of extensive electrofishing to remove northern squawfish.

In 1991 and 1992, the Columbia River flows on the second release date were higher than on the first release date, about 8% higher in 1992 and 27% higher in 1991. In 1993, flows were almost identical on the two release dates (Table G-4). About 2,000 northern squawfish were removed from the study area between the two release dates in all three years; the difference in survival benefit for midstream Columbia River releases compared to Tanner Creek releases following electrofishing efforts declined through the years (22%, 51%, and 129% decline in survival benefit for 1991, 1992, and 1993, respectively). The effectiveness of localized northern squawfish removal at reducing the survival differences between midstream Columbia River and Tanner Creek releases may also be affected by the dispersal rate of study fish from the area of release. Dispersal rate would affect the period of time that study fish were exposed to the local northern squawfish population.

It is difficult to determine if the generally high numbers and catch rates of predators in the study area occurred because northern squawfish congregated near the hatchery release site or because high densities of northern squawfish were prevalent throughout the entire study area. The high catches of northern squawfish along the Oregon shoreline at Transects 03 and 04 support the latter explanation (Figure 5). In all three years (1991-1993), CWT recoveries from the stomachs of northern squawfish were concentrated at transects closest to the Tanner Creek release site; nearly all the CWTs recovered were from the Tanner Creek release groups, which suggested that juvenile salmonids released from the hatchery were more vulnerable to predation by northern squawfish in the river region near Bonneville Hatchery than juveniles released in midstream. In 1993, the CPUE for northern squawfish fluctuated during the removal period, and was lower for the dates following the second pair of juvenile salmon releases, which indicated little influx of northern squawfish into the study area in response to the second release of juvenile salmon. The sharp drop in numbers of CWTs in the digestive tracts of northern squawfish by the final day of electrofishing indicated emigration of the released salmon.

It is difficult to attribute the apparent lack of survival benefit for midstream Columbia River-released fish in 1993 to the removal of only 2,866 northern squawfish. Rather, a general decline in the proportion of the larger-sized northern squawfish in 1992 and 1993 may better explain the decline.

CONCLUSIONS

1) Subyearling chinook salmon from Bonneville Hatchery released into the midstream Columbia River prior to electrofishing efforts exhibited significantly higher survival rates than fish released into Tanner Creek. We believe the difference in survival is in part related to predation by northern squawfish on fish released at the hatchery.

2) The predominance of CWTs from Tanner Creek-released juvenile salmon in the digestive tracts of northern squawfish indicated that juvenile salmon released from the hatchery were more vulnerable to predation by northern squawfish located in the river region near Bonneville Hatchery than juveniles released in midstream,

3) The survival difference between midstream Columbia River and Tanner Creek release groups may be affected by the dispersal rate of study fish from the area of release. More rapid dispersal may be a result of tailwater elevation below Bonneville Dam and consequent hydraulic conditions at the confluence of Tanner Creek, and degree of smoltification .

4) It was difficult to determine if the high numbers and catch rates of predators at the transects nearest Tanner Creek occurred in response to the hatchery release or to high densities of northern squawfish throughout the study area.

5) It appeared that the numbers and size of northern squawfish in the study area have declined in recent years and that this general decline in population abundance contributed to the effectiveness of localized predator removal during the 1993 research. Electrofishing to remove northern squawfish from the migration route of juvenile salmon released from Bonneville Hatchery appeared to eliminate the survival difference between midstream Columbia River and Tanner Creek release groups under the conditions in 1993.

REFERENCES

Bergman, P. K., K. B. Jefferts, H. F. Fiscus, and R. C. Hager. 1968. A preliminary evaluation of an implanted coded wire fish tag. Wash. Dep. Fish., Fish. Res. Pap. 3(1):63-84.

Dawley, E. M., L. G. Gilbreath, and R. D. Ledgerwood. 1988. Evaluation of juvenile salmonid survival through the Second Powerhouse turbines and downstream migrant bypass system at Bonneville Dam, 1987. Report to U.S. Army Corps of Engineers, Contract DACW57-87-F-0323, 36 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Dawley, E. M., R. D. Ledgerwood, and A. L. Jensen. 1985. Beach and purse seine sampling of juvenile salmonids in the Columbia River estuary and ocean plume, 1977-1983. Volume I: procedures, sampling effort, and catch data. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/NWC-74, 260 pp.

Hansel, H. C., S. D. Duke, P. T. Lofy, and G. A. Gray. 1988. Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. Trans. Amer. Fish. Soc. 117:55-62.

Ledgerwood, R. D., E. M. Dawley, P. J. Bentley, L. G. Gilbreath, T. P. Poe, and H. L. Hansen. 1993. Effectiveness of predator removal for protecting juvenile fall chinook salmon released from Bonneville Hatchery, 1991. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-9, 63 pp.

Ledgerwood, R. D., E. M. Dawley, L. G. Gilbreath, P. J. Bentley, B. P. Sandford, and M. H. Schiewe. 1990. Relative survival of subyearling chinook salmon which have passed Bonneville Dam via the spillway or the Second Powerhouse turbines or bypass system in 1989, with comparisons to 1987 and 1988. Report to U.S. Army Corps of Engineers, Contract E85890024/E86890097, 64 pp. plus Appendixes. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Ledgerwood, R. D., E. M. Dawley, L. G. Gilbreath, L. T. Parker, T. P. Poe, and H. L. Hansen. 1994. Effectiveness of predator removal for protecting juvenile fall chinook salmon released from Bonneville Hatchery, 1992. Pages 295-360 *in* C. F. Willis and A. A. Nigro, editors. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River basin. 1992 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

Mighell, J. H. 1969. Rapid cold-branding of salmon and trout with liquid nitrogen. J. Fish. Res. Board Can. 26:2765-2769.

Petersen, J. H., M. G. Mesa, J. Hall-Griswold, W. C. Schrader, G. W. Short, and T. P. Poe. 1990. Magnitude and dynamics of predation on juvenile salmonids in Columbia and Snake River reservoirs. Report to Bonneville Power Administration, Portland Oregon. Contract DE-AI79-88BP91964. 82 pp.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry, 2nd Edition. W. H. Freeman and Company, San Francisco, 776 pp.

Willis C. F., and A. A. Nigro, editors. 1994. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1992 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

Zar, J. H. 1974. Biostatistical analysis. Prentice-Hall. Englewood Cliffs, New Jersey. 620 pp.

APPENDIX G-1

Juvenile Salmon Marking, Release, and Jones Beach Recovery Information

Appendix Table G-l. 1. Tag loss estimates among marked groups of subyearling chinook salmon after a 30day holding period for Tanner Creek and midstream Columbia River release-groups, 1993.

Release dates	Coded wire tag (AG D1 D2)[a]	NT[b]	Sample"
Tanner Creek releases			
21 June	23 30 21	18	492
25 June	23 30 22	36	489
Midstream releases			
21 June	23 30 23	23	503
25 June	23 30 24	13	482

a CWT code key: AG D1 D2 = Agency code, Data 1 code, Data 2 code.
b NT = Number of branded fish in the sample with no coded wire tag.
6 Number of fish checked for the presence of coded wire tags.

Appendix Table G-1.2. Daily purse seine and beach seine fishing effort, water temperatures, and Secchi disk transparency measurements at Jones Beach, 1993.

Date	Number of sets		Temp.	Secchi	Date	Number of sets		Temp.	Secchi
	Purse	Beach	°C	depth (m)		Purse	Beach	°C	depth (m)
18 Jun	2	0	17	--[d]	30 Jun	20	0	18	1.2
19 Jun	0	0	--	--	1 Jul	15	3	18	1.2
20 Jun	0	0	--	--	2 Jul	16	0	17	1.1
21 Jun	3	2	17		3 Jul	13	2	17	1.1
22 Jun	4	2	17	1.1	4 Jul	13	0	17	
23 Jun	8	0	17	1.2	5 Jul	9	0	18	1.2
24 Jun	8	1	16	1.1	6 Jul	13	2	18	1.1
25 Jun	10	0	17	1.2	7 Jul	13	0	18	1.2
26 Jun	13	0	17	1.1	8 Jul	8	2	18	1.1
27 Jun	13	2	17	1.4	9 Jul	7	0	18	1.2
28 Jun	12	1	18	1.1	10 Jul	2	0	18	1.4
29 Jun	15	0	18	1.2	11 **Jul**	3	0	18	1.2
					12 **Jul**	1	0	18	--

[d] Dashes indicate data not available.
[e] First recovery of study fish.

Appendix Table G-1.3. Daily recoveries, recoveries standardized for effort, dates of median fish recovery, and movement rates to Jones Beach of marked subyearling chinook salmon released from Bonneville Hatchery into Tanner Creek and transported from the hatchery for release in midstream Columbia River, 1993.

Date of recovery	Released 21 June — Treatments and tag code (AG D1 D2)[a]: Tanner Creek 23 30 21 — Purse A[b]	Purse S[c]	Beach A	Beach S	Total A	Total S	Midstream Columbia 23 30 23 — Purse A	Purse S	Beach A	Beach S	Total A	Total S
25 Jun	7	8	NE		7	8	11	13	NE		11	13
26 Jun	53	49	NE	--	53	49	70	65	NE		70	65
27 Jun	134	124	3		137	124	171	158	3		174	158
28 Jun	73	73	3	--	76	73[d]	66	66	3		69	66[d]
29 Jun	37	30	NE	--	37	30	54	43	NE		54	43
30 Jun	45	27	NE	--	45	27	59	35	NE	--	59	35
1 Jul	30	24	6		36	24	36	29	4		40	29
2 Jul	27	20	NE		27	20	30	23	NE		30	23
3 Jul	20	18	1		21	18	28	26	5		33	26
4 Jul	24	22	NE		24	22	27	25	NE		27	25
5 Jul	12	16	NE		12	16	10	13	NE		10	13
6 Jul	18	17	0		18	17	18	17	0	--	18	17
7 Jul	21	19	NE		21	19	16	15	NE	--	16	15
8 Jul	8	12	0	--	8	12	11	17	0	--	11	17
9 Jul	1	2	NE	--	1	2	4	7	NE	--	4	7
10 Jul	1	6	NE		1	6	0	0	NE	--	0	0
11 Jul	4	16	NE	--	4	16	0	0	NE	--	0	0
12 Jul	1	12	NE		1	12	0	0	NE	--	0	0
Total	516	495	13	0	529	495	611	550	15	0	626	550
Recovery (%)	0.54	0.52	0.01	0.00	0.55	0.52	0.64	0.58	0.02	0.00	0.66	0.58
Mvmt rate[e]					*22.4*						*22.4*	

Appendix Table G-1.3. Continued.

Date of recovery	Released 25 June: Treatments and tag code (AG Dl D2)[a] — Tanner Creek 23 30 22 — Purse A[b]	Purse S[c]	Beach A	Beach S	Total A	Total S	Midstream Columbia 23 30 24 — Purse A	Purse S	Beach A	Beach S	Total A	Total S
25 Jun	0	0	NE	--	0	0	0	0	NE	--	0	0
26 Jun	0	0	NE		0	0	0	0	NE		0	0
27 Jun	0	0	0		0	0	0	0	0		0	0
28 Jun	1	1	0		1	1	0	0	0	--	0	0
29 Jun	42	34	NE		42	34	38	30	NE		38	30
30 Jun	71	43	NE		71	43	83	50	NE		83	50
1 Jul	89	71	3	--	92	71	88	70	4		92	70
2 Jul	85	64	NE		85	64	89	67	NE		89	67
3 Jul	64	59	4	--	68	59[d]	73	67	0		73	67[d]
4 Jul	53	49	NE	--	53	49	54	50	NE		54	50
5 Jul	21	28	NE	--	21	28	22	29	NE		22	29
6 Jul	49	45	0		49	45	43	40	0		43	40
7 Jul	53	49	NE	--	53	49	45	42	NE		45	42
8 Jul	17	26	1	--	18	26	18	27	0		18	27
9 Jul	19	33	NE		19	33	18	31	NE		18	31
10 Jul	12	24	NE		12	24	10	25	NE		10	25
11 Jul	4	16	NE	--	4	16	5	20	NE	--	5	20
12 Jul	0	0	NE		0	0	0	0	NE		0	0
Total	580	541	8	0	588	541	586	548	4	0	590	548
Recovery (%)	0.63	0.59	0.01	0.00	0.64	0.59	0.60	0.56	0.00	0.00	0.60	0.56
Mvmt rate[e]						19.6						19.6

[a] AG Dl D2 = Agency code, Data 1 code, Data 2 code.
[b] A = Actual daily purse seine or beach seine catch. NE = no sampling effort.
[c] S = Standardized daily catch. Purse seine data standardized to a 12 set per day effort; beach seine effort was limited and not used for data standardization.
[d] Day that the mediin fish was captured (standardized purse seine effort).
[e] Mvmt rate = Movement rate (km/day) = distance traveled (RKm 232 to RKm 75) ÷ travel time (days from release to median fish recovery).

APPENDXX G-2

Northern Squawfiih Electrofiihiig Information

Appendix Table G-2.1. Northern squawfish electrofishing daily effort and catch results, 1993.

Electrofishing period[a]	Electrofishing date	Electrofishing location[b]	Start time[c]	Effort (sec)[d]	Catch (no.)	CPUE (no. /h)[d]
1	22 Jun	01	0326	1,802	27	53.9
2	23 Jun	01	0216	1,271	29	82.1
2	22 Jun	01	2133	970	51	189.3
3	24 Jun	01	0208	1,112	27	87.4
3	23 Jun	01	2115	1,027	25	87.6
4	25 Jun	01	0110	804	29	129.9
4	24 Jun	01	2112	1,104	23	75.0
5	27 Jun	01	0100	1,602	7	15.7
6	28 Jun	01	0155	599	13	78.1
6	27 Jun	01	2107	1,375	31	81.2
6	27 Jun	01	2124	775	32	148.6
Subtotal				12,441	294	
Mean				1,131.0	26.7	93.5
SE				109.0	3.4	14.2
1	22 Jun	02	0408	1,911	60	113.0
2	23 Jun	02	0335	1,738	70	145.0
2	22 Jun	02	2226	1,995	115	207.5
3	24 Jun	02	0304	1,975	64	116.7
3	23 Jun	02	2150	1,861	76	147.0
4	24 Jun	02	2215	2,400	83	124.5
5	27 Jun	02	0309	1,792	26	52.2
5	26 Jun	02	2248	1,901	59	111.7
Subtotal				15,573	553	
Mean				1,946.6	69.1	127.2
SE				71.6	8.9	15.4
1	22 Jun	03	0517	1,866	41	79.1
2	23 Jun	03	0450	1,766	47	95.8
2	22 Jun	03	2313	1,807	223	444.3
3	24 Jun	03	0356	1,242	40	115.9
3	23 Jun	03	2327	1,820	164	324.4
4	25 Jun	03	0412	1,800	51	102.0
4	24 Jun	03	2305	1,800	110	220.0
5	27 Jun	03	0406	1,580	31	70.6
5	26 Jun	03	2336	1,319	78	212.9
6	27 Jun	03	2045	1,750	15	30.9
Subtotal				16,750	800	--
Mean				1,675.0	80.0	169.6
SE				70.2	21.1	41.4

Appendix Table G-2.1. Continued.

Electrofishing period[a]	Electrofishing date	Electrofishing location[b]	Start time'	Effort (sec)[d]	Catch (no.)	CPUE (no. /h)[d]
4	25 Jun	0 4	0300	1,827	29	57.1
Subtotal				1,827	29	--
Mean				1,827.0	29.0	57.1
SE					--	--
1	22 Jun	TC	0506	99	7	254.5
2	23 Jun	TC	0315	231	9	140.3
2	22 Jun	TC	2215	407	33	291.9
3	24 Jun	TC	0325	449	13	104.2
3	23 Jun	TC	2205	250	14	201.6
4	25 Jun	TC	0200	319	12	135.4
4	24 Jun	TC	2200	513	24	168.4
Subtotal				2,268	112	
Mean				324.0	16.0	185.2
SE				54.1	3.5	25.7
1	22 Jun	W1	0315	1,806	84	167.4
2	23 Jun	W1	0238	1,531	132	310.4
2	22 Jun	W1	2058	1,443	57	142.2
3	24 Jun	W1	0202	1,896	68	129.1
3	23 Jun	W1	2058	1,492	11	26.5
4	25 Jun	W1	0200	1,800	78	156.0
4	24 Jun	W1	2100	931	5	19.3
5	27 Jun	W1	0150	1,802	74	147.8
5	26 Jun	W1	2057	1,930	28	52.2
6	27 Jun	W1	2315	1,808	35	69.7
Subtotal				16,439	572	
Mean				1,643.9	57.2	122.1
SE				96.2	12.2	27.3
1	22 Jun	w 2	0645	1,098	15	49.2
2	23 Jun	w 2	0405	1,060	13	44.2
2	22 Jun	w 2	2310	1,800	25	50.0
3	24 Jun	w 2	0413	1,038	7	24.3
3	23 Jun	w 2	2225	1,557	48	111.0
4	25 Jun	w 2	0341	1,265	13	37.0
4	24 Jun	w 2	2241	1,528	25	58.9
5	27 Jun	w 2	0145	1,629	18	39.8
5	26 Jun	w 2	2247	1,130	2	6.4
6	28 Jun	w 2	0245	1,578	24	54.8
6	27 Jun	w 2	2254	1,438	14	35.0
Subtotal				15,121	204	
Mean				1,374.6	18.5	46.4
SE				80.3	3.7	7.8

Appendix Table G-2.1. Continued.

Electrofishing period[a]	Electrofishing date	Electrofishing location[b]	Start time[c]	Effort (sec)[d]	Catch (no.)	CPUE (no. /h)[d]
1	22 Jun	w 3	0643	1,906	19	35.9
2	23 Jun	w 3	0020	1,167	23	71.0
2	23 Jun	w 3	0455	1,802	45	89.9
3	24 Jun	w 3	0445	1,631	63	139.1
3	23 Jun	w 3	2052	1,388	30	77.8
4	25 Jun	w 3	0001	621	5	29.0
4	25 Jun	w 3	0430	1,759	29	59.4
5	27 Jun	w 3	0232	2,311	9	14.0
5	26 Jun	w 3	2330	1,276	14	39.5
6	28 Jun	w 3	0350	1,169	29	89.3
6	27 Jun	w 3	2338	1,057	36	122.6
Subtotal				16,087	302	--
Mean				1,462.5	27.5	69.8
SE				142.5	5.0	11.8
Totals				96,506	2,866	
Mean				1,423.1	40.5	108.9
SE				181.6	8.7	18.1

[a] Sampling periods generally began at 2 100 h and terminated the following morning about 0900 h.
[b] Locations codes (two characters): TC = Tanner Creek transect; other Columbia River transects, where first character 0 = Oregon shoreline and W = Washington shoreline; second character, l-4, transects located progressively downstream (refer to Figure 3 for precise locations).
[c] Time that the electrofishing effort began.
[d] Time that the electrofishing unit was powered on.
[e] CPUE = catch of northern squawfish per unit effort of electrofishing.

Appendix Table G-2.2. Coded-wire tags from ingested juvenile salmon recovered in the stomachs of northern squawfish during electrofishing efforts, 1993.

Electrofishing period[b]	Date	Start time'	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG Dl D2)[e]
			Data for Tanner Creek release 21 June 1993			
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
Subtotal						24
1	22 Jun	0506	2001	1	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	5	TC	233021
1	22 Jun	0506	2001	5	TC	233021
1	22 Jun	0506	2001	6	TC	233021
Subtotal						10
1	22 Jun	0408	2252	6	02	233021
1	22 Jun	0408	2252	6	02	233021
1	22 Jun	0408	2252	6	02	233021
1	22 Jun	0408	2252	7	02	233021
1	22 Jun	0408	2252	7	02	233021

Appendix Table G-2.2. Continued.

Electrofishing period[b]	Date	Start time[c]	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG D1 D2)[e]
1	22 Jun	0408	2252	7	0 2	233021
1	22 Jun	0408	2252	7	0 2	233021
1	22 Jun	0408	2252	8	0 2	233021
1	22 Jun	0408	2252	8	0 2	233021
1	22 Jun	0408	2252	8	0 2	233021
1	22 Jun	0408	2252	9	0 2	233021
1	22 Jun	0408	2252	9	0 2	233021
1	22 Jun	0408	2252	9	0 2	233021
1	22 Jun	0408	2252	9	0 2	233021
1	22 Jun	0408	2252	9	0 2	233021
1	22 Jun	0408	2252	13	0 2	233021
1	22 Jun	0408	2252	13	0 2	233021
1	22 Jun	0408	2252	13	0 2	233021
1	22 Jun	0408	2252	16	0 2	233021
1	22 Jun	0408	2252	18	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	21	0 2	233021
1	22 Jun	0408	2252	21	0 2	233021
1	22 Jun	0408	2252	23	0 2	233021
1	22 Jun	0408	2252	27	0 2	233021
1	22 Jun	0408	2252	27	0 2	233021
1	22 Jun	0408	2252	28	0 2	233021
1	22 Jun	0408	2252	28	0 2	233021
1	22 Jun	0408	2252	28	0 2	233021
1	22 Jun	0408	2252	31	0 2	233021
1	22 Jun	0408	2252	31	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	50	0 2	233021
1	22 Jun	0408	2252	50	0 2	233021

Appendix Table G-2.2. Continued.

Electrofishing period[b]	Date	Start time[c]	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG D1 D2)[e]
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	52	O2	233021
1	22 Jun	0408	2252	52	O2	233021
1	22 Jun	0408	2252	52	O2	233021
1	22 Jun	0408	2252	54	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 fun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
Subtotal						80
Total period 1 (all sites)						114
2	22 Jun	2133	2011	22	O1	233021
2	22 Jun	2133	2011	23	O1	233021
Subtotal						2

Appendix Table G-2.2. Continued.

Electrofishing period[b]	Date	Start time[c]	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG D1 D2)[e]
2	22 Jun	2215	2012	22	TC	233021
2	22 Jun	2215	2012	22	TC	233021
2	22 Jun	2215	2012	27	TC	233021
2	22 Jun	2215	2012	27	TC	233021
2	22 Jun	2215	2012	27	TC	233021
2	23 Jun	0315	2016	6	TC	233021
Subtotal						6
2	22 Jun	2226	2262	6	0 2	233021
2	22 Jun	2226	2262	6	0 2	233021
2	22 Jun	2226	2262	8	0 2	233021
2	22 Jun	2226	2262	8	0 2	233021
2	22 Jun	2226	2262	8	0 2	233021
2	22 Jun	2226	2262	8	0 2	233021
2	22 Jun	2226	2262	8	0 2	233021
2	22 Jun	2226	2262	29	0 2	233021
2	22 Jun	2226	2262	29	0 2	233021
2	22 Jun	2226	2262	29	0 2	233021
2	22 Jun	2226	2262	29	0 2	233021
2	22 Jun	2226	2262	112	0 2	233021
2	23 Jun	0335	2265	7	0 2	233021
2	23 Jun	0335	2265	7	0 2	233021
2	23 Jun	0335	2265	7	0 2	233021
2	23 Jun	0335	2265	7	0 2	233021
2	23 Jun	0335	2265	15	0 2	233021
2	23 Jun	0335	2265	16	0 2	233021
2	23 Jun	0335	2265	16	0 2	233021
2	23 Jun	0335	2265	16	0 2	233021
2	23 Jun	0335	2265	27	0 2	233021
2	23 Jun	0335	2265	27	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	57	0 2	233021
2	23 Jun	0335	2265	63	0 2	233021
2	23 Jun	0335	2265	63	0 2	233021
2	23 Jun	0335	2265	63	0 2	233021
Subtotal						33

Appendix Table G-2.2. Continued.

Electrofishing period[b]	Date	Start time[c]	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG D1 D2)[e]
Total period 2 (all sites)						41
3	24 Jun	0208	2022	1	01	233021
3	24 Jun	0325	2023	5	TC	233021
Total period 3 (all sites-l each for 01 and TC)						2
Grand total this tag number all periods all sites.						157
Data for Midstream Columbia River release 21 June 1993						
1	22 Jun	0408	2252	13	0 2	233023
1	22 Jun	0408	2252	27	0 2	233023
2	22 Jun	2226	2262	8	0 2	233023
Grand total this tag number all periods all sites.					3	
Data for tagged non-study fish						
2	23 Jun	0216	2015	22	01	635003
2	23 Jun	0238	2264	42	W1	076135
2	23 Jun	0238	2264	3	W1	076137
2	23 Jun	0238	2264	108	W1	076137
3	23 Jun	2225	2020	3	w 2	076137
3	23 Jun	2225	2020	3	w 2	076332
4	25 Jun	0200	2280	43	W1	076332
Grand total non-study tags all periods all sites.					7	

[a] Individual specimens of northern squawfish are identified as a combination of collection number and predator number.
[b] Sampling periods generally began at 2100 h and terminated the following morning about 0900 h.
[c] Time that the electrofishing effort began.
[d] Location codes (two characters): TC = Tanner Creek transect; other Columbia River transects, where first character 0 = Oregon shoreline and W = Washington shoreline; second character, l-4, transects located progressively downstream (refer to Figure 3 for precise locations).
[e] CWT code key AG D1D2 = Agency code. Data I code, and Data 2 code.

APPENDIX G-3

Statistical Analysis of Juvenile Salmon Recovery Data

A. Chi-square goodness of fit analysis was used to evaluate differences among observed recoveries (Appendix Table G-1.3) through time for different treatment groups released on the same day (Sokal and Rohlf 1981). A non-significant result indicated that there was equal probability of capture at Jones Beach for each treatment group (i.e., that the groups were adequately mixed). Results of this analysis are shown below. For additional details of this procedure see Dawley et al. (1989); Appendix D.

H_o: There was homogeneity between recovery distributions of treatments.

Release date	Seine type	Chi-sauare	df	P
21 June	purse plus beach	10.33	14	0.7377
25 June	purse plus beach	2.91	12	0.9962

Conclusion: No evidence to suggest there is non-homogeneity between treatment recovery distributions.

B. Paired difference z-tests were used to evaluate the benefits of midstream Columbia River release over Tanner Creek release and to evaluate the effects of northern squawfish removal efforts on the difference between midstream- and Tanner Creek-releases. Similar analyses were preformed on purse-seine plus beach-seine recoveries (section la-lc) and purse-seine recoveries alone (section 2a-2c). Recoveries in the beach seine were insufficient for a meaningful analysis (< 0.1%). Consider the following notation:

P_{tc1} = true survival to and recovery at Jones Beach of fish released in Tanner Creek before squawfish removal on 21 June.
p_{tc1} = estimate of P_{tc1} = recovery proportion at Jones Beach of fish released at Tanner Creek on 21 June

Similar explanations follow for P_{tc2}, p_{tc2}, P_{mc1}, p_{mc1}, P_{mc2} and p_{mc2}

where: tc denotes Tanner Creek.
mc denotes midstream Columbia River
1 denotes releases on 21 June, before squawfish removal
2 denotes releases on 25 June, after squawfish removal

R_{ij} = release number for group i, j where i = tc, mc and j = **1, 2**

$v(p_{ij}) = p_{ij}(1-p_{ij}) \div R_{ij}$ is the estimated variance of p_{ij}

For the three null hypotheses tested below, we assumed z (as defined below) would follow a standard normal distribution.

1) Total catch--purse seine plus beach seine.

a) The null hypothesis for testing whether recoveries of midstream Columbia River-released fish were different than Tanner Creek-released fish for the first release pair was:

$$H_o: (P_{mc1} - P_{tc1}) = 0$$

The test statistic was:

$$z = \frac{(p_{mc1} - p_{tc1})}{\sqrt{v(p_{mc1}) + v(p_{tc1})}}$$

The relevant statistics for the first release pair were:

$p_{mc1} = 626 \div 94{,}938 = 0.006594$
$p_{tc1} = 529 \div 96{,}013 = 0.005510$

Then,

$$z = \frac{(0.006594 - 0.005510)}{\sqrt{\frac{0.006594(0.993406)}{94938} + \frac{0.005510(0.994490)}{96013}}}$$

$= 0.000355 = 3.053$, ***p-value = 0.0023***

Conclusion: The recovery rate for midstream Columbia River-released fish was significantly higher than for Tanner Creek-released fish; the difference was 19.7 % .

b) The null hypothesis for testing whether recoveries of midstream Columbia River-released fish were different than Tanner Creek-released fish for the second release pair was:

$$H_o: (P_{mc2} - P_{tc2}) = 0$$

The test statistic was:

$$z = \frac{(p_{mc2} - p_{tc2})}{\sqrt{v(p_{mc2}) + v(p_{tc2})}}$$

The relevant statistics for the second release pair were:

$p_{mc2} = 590 \div 97{,}835 = 0.006031$
$p_{tc2} = 588 \div 91{,}926 = 0.006396$

Then,

$$z = \frac{(0.006031 - 0.006396)}{\sqrt{\frac{0.006031(0.993969)}{97835} + \frac{0.006396(0.993604)}{91926}}}$$

$$= \frac{-0.000365}{0.000361} = -1.0111, \; \textbf{\textit{p-value}} = 0.3120$$

Conclusion: The recovery rate for midstream Columbia River-released fish was not significantly higher than for Tanner Creek-released fish; the difference was -5.7%.

c) The null hypothesis for testing whether northern squawfish removal had a significant benefit for Tanner Creek-released fish was:

$$H_o: (P_{mc1} - P_{tc1}) - (P_{mc2} - P_{tc2}) = 0$$

The test statistic was:

$$z = \frac{(p_{mc1} - p_{tc1}) - (p_{mc2} - p_{tc2})}{\sqrt{v(p_{mc1}) + v(p_{tc1}) + v(p_{mc2}) + v(p_{tc2})}}$$

The relevant statistics for the study were:

P_{mc1} = 626 ÷ 94,938 = 0.006594
p_{tc1} = 529 ÷ 96,013 = 0.005510
P_{mc2} = 590 ÷ 97,835 = 0.006031
p_{tc2} = 588 ÷ 91,926 = 0.006396

Then,

$$z = \frac{(0.006594 - 0.005510) - (0.006031 - 0.006396)}{\sqrt{\frac{0.006594(0.993406)}{94938} + \frac{0.005510(0.994490)}{96013} + \frac{0.006031(0.993969)}{97835} + \frac{0.006396(0.993604)}{91926}}}$$

$$= \frac{0.00145}{0.000505} = 2.871 \quad \textbf{\textit{p-value}} = 0.0041$$

Conclusion: The effect of removing northern squawfish from the migration route of Tanner Creek-released fish was significant; the reduction was 128.9% ((19.7% - (-5.7)% ÷ 19.7) * 100).

2) Purse seine recoveries.

a) The null hypothesis for testing whether recoveries of midstream Columbia River-released fish were different than Tanner Creek-released fish for the first release pair was:

H,: $(P_{mc1} - P_{tc1}) = 0$; $z = 3.028$; p-value = 0.0025

b) The null hypothesis for testing whether recoveries of midstream Columbia River-released fish were different than Tanner Creek-released fish for the second release pair was:

$$H_o: (P_{mc2} - P_{tc2}) = 0; \ z = -1.0160; \ \text{p-value} = 0.3096$$

c) The null hypothesis for testing whether northern squawfish removal had a significant benefit for Tanner Creek-released fish was:

$$H_o: (P_{mc1} - P_{tc1}) - (P_{mc2} - P_{tc2}) = 0; \ z = 2.7510; \ \text{p-value} = 0.0059$$